COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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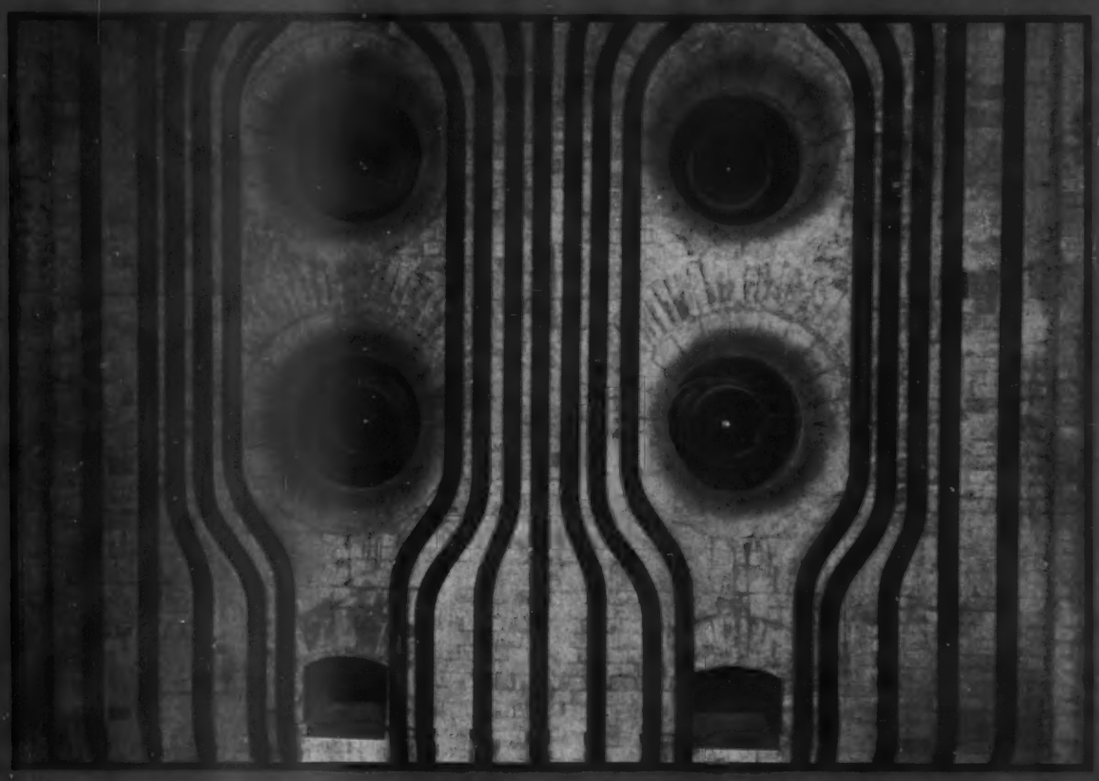


Front wall of furnace in one of two units recently placed in service in large industrial plant

Trends and Developments in Industrial Turbines

Central Station Flow Diagrams

Design of High-Pressure Boilers

HAS "LARGEST" ANY SIGNIFICANCE?

IT has often been said, sometimes disparagingly, that Americans are devoted to the idea of bigness and are prone to attach undue significance to statistics or achievements that are "tops" in their class.

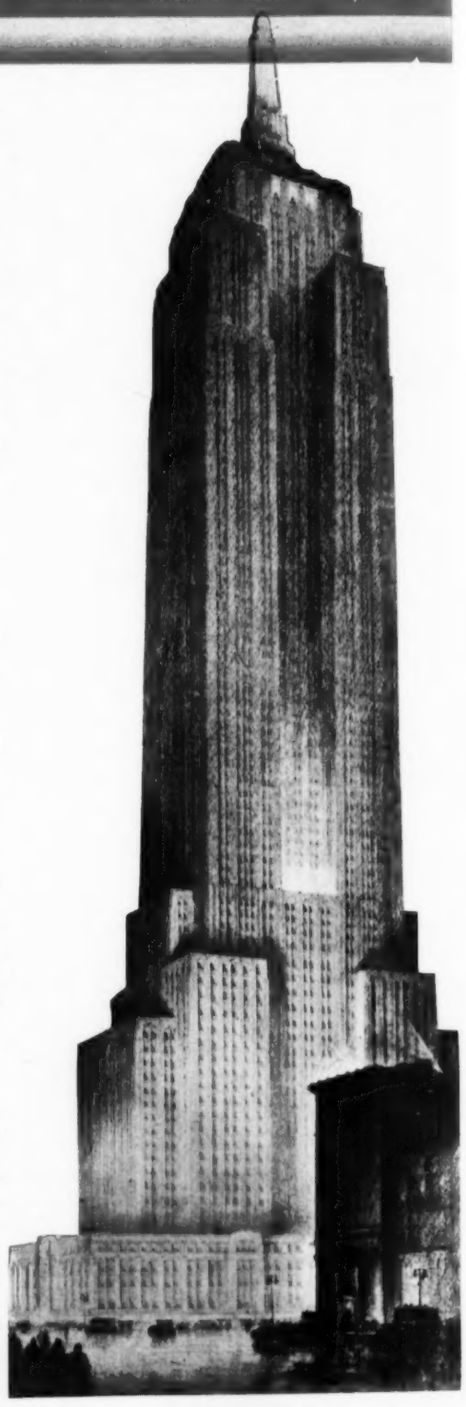
Nevertheless, in certain fields of human endeavor, the term "largest" is frequently a significant indicator both of high achievement and new value. For example, the progress in equipment design and manufacturing techniques that has made it possible to concentrate great steam-generating capacity in single units represents real achievement. Such units have made possible substantial economies in space, investment and operating cost per unit of output.

The problems involved in designing and building large steam-generating units are of unusual magnitude and complexity. Few organizations have the experience, personnel and manufacturing facilities required for their satisfactory solution.

The following résumé of the facts concerning such units indicates the position Combustion Engineering has attained in this class of work.

1 ***Only six boilers have been installed throughout the world which have operated at rates of 1,000,000 or more lb of steam per hr. Four of these are complete CE Units. Combustion Engineering is now installing its fifth 1,000,000-lb unit and has recently completed the installation of a unit designed to produce 900,000 lb per hr.***

2 ***There are 35 boilers in the United States which have produced steam at rates of 500,000 or more lb per hr. 22 of these are CE Boilers, most of which have CE furnace, firing and heat recovery equipment. Combustion Engineering now has on order eight additional units in this class.***



Every CE installation is engineered and built to assure, as far as possible, the best economic results which can be justified for the particular conditions. An adequate line of boiler, fuel-burning and related equipment, modern manufacturing facilities and an exceptionally competent engineering staff are combined to this end. Capacities of CE installations range from 1000 to over a 1,000,000 lb of steam per hr.

C-E

COMBUSTION ENGINEERING COMPANY, INC.

200 MADISON AVE., NEW YORK *Canadian Associate: Combustion Engineering Corporation, Ltd., Montreal*

A-334

COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME EIGHT NUMBER SEVEN

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FOR JANUARY 1937

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CCA

PHOSCALOID'S SIMPLICITY IN CONDITIONING BOILER WATERS

Provides in one product:

● *A concentrated inexpensive source for PO_4 and colloids in requisite proportions for de-sludging and other purposes, together with—*

● *Indicators for controlling the mixture of caustics and Phoscaloid;*

● *Is a soda-free compound with a deep red color that becomes light yellow and is converted totally to a mono-phosphate upon the addition of caustic soda in the amount of ¼th the weight of the Phoscaloid in use.*

THE change in color from deep red to light yellow definitely measures the completion of this one conversion. The further addition of caustic soda to the mono-phosphate solution in the amount of ¼th of Phoscaloid changes the yellow color to pink. This also indicates a complete conversion of mono-sodium to di-sodium phosphate. In each case the change in color represents the definite completion in the conversion of one compound to another.

The complete conversion of the di-sodium phosphate to tri-sodium phosphate requires the use of this same proportionate weight of ¼th caustic to one Phoscaloid, and where the facts for the purpose are based on color changes in the production of mono- and di-sodium phosphate. Both di- and tri-sodium phosphates can be made direct from Phoscaloid through the one addition of caustic soda in the amount of ½ the weight for the Phoscaloid in use when converting Phoscaloid to di-sodium phosphate, and in the amount of ¾ the weight of the Phoscaloid in use when converting all the Phoscaloid to tri-sodium phosphate. This same set-up allows for any required phosphate combinations, through mixtures of caustics and Phoscaloid in proportions other than those given—all for the purpose of correcting any boiler scale conditions. It is equally as flexible in controlling the pH in the boiler concentrates for protecting the boilers against corrosion.

This definite PO_4 content of Phoscaloid also makes it easy to determine the treatment requirements for a specific water, because each pound will remove one pound of calcium (terms calcium carbonate) from the feedwater or condition 10,000 gallons of $^7/_{10}$-grain water, or 1,000 gallons 7-grain water.

Phoscaloid also possesses the property of neutralizing these same equivalents and contains colloids that will extend protection to boilers against sludge inclusions in amounts approximating ten times these same equivalents.

These simple properties of Phoscaloid have special application in conditioning lime-soda and zeolited waters against the effects of these high soda and high silica influences on boiler operations. Its use represents a control in the conditioning of feedwater that must eventually bring better results and lower costs.

CYRUS Wm. RICE & CO., INC.
HIGHLAND BUILDING—PITTSBURGH, PA.

EDITORIAL

When Shutting Down Mills

Practice among operating companies differs as to the procedure employed in clearing mills of pulverized coal when they are taken out of service, in order to reduce the hazard of fire or dust explosion.

Inasmuch as mill drying has become general with direct firing, the mill should be cleared of coal if it is to be out of service for more than five or six hours. For shorter periods this is usually not so important as it requires some time for heating up to the point of spontaneous combustion.

When a mill is to be taken out of service for such a period or longer it is well, about half an hour before stopping, to shut off the hot air supply in order to cool the mill gradually; then continue operation until the mill is practically empty. However, as the amount of coal decreases the mixture will become leaner and it is important to have the torch in the furnace lighted to insure ignition of the coal. In most types, with the possible exception of the impact mill, some coal will remain, but this can be removed manually by means of a hoe.

If a fire is discovered in a mill, the introduction of an inert gas, such as CO_2 or flue gas high in CO_2, should prove effective and more convenient than water or even steam which condenses, and both of which form a sludge with the pulverized coal. This is messy and difficult to clean out.

Conditions in individual plants differ and frequently render special procedures necessary, but the present wide application of pulverized coal firing makes adherence to a few general principles desirable.

Load Ahead of Capacity Increase

The 1936 generation of electricity by central stations, both private and municipal and including 479 million kilowatt-hours produced by the TVA, amounted to about 106 billion kilowatt-hours—an increase of more than thirteen per cent over 1935 and sixteen per cent over 1929. Of this total, approximately sixty-four per cent was generated by steam, thirty-five per cent by water power and about one per cent by internal-combustion engines. An additional three billion kilowatt-hours was purchased by the central station industry from outside sources such as Canada, industrial and railway plants.

Additional steam capacity that actually went into service during the past year was small compared with the increased load, being about 200,000 kilowatts, but it is anticipated that nearly a million kilowatts will be added during the present year among the numerous steam-plant extensions now under construction. This, of course, is exclusive of a small amount of hydro capacity to be added by the utilities and a large amount involved in several Federal water-power projects. The latter, however, is not likely to be an important factor in meeting immediate industrial demands because of the locations of these projects.

It is significant that the slope of the curve representing output plotted against years, is now practically the same as that for the period from 1921 to 1929, representing normal growth during active years. How long this rate of increase will continue is a matter of opinion, but the assumption that it will be maintained for the next two or three years finds substantiation in the fact that industrial production is still considerably under that of 1929, although domestic consumption since then has increased by about fifty-seven per cent.

However, the million kilowatts of steam capacity to be added during the present year will fall short of keeping pace with the present rate of load increase, making due allowance for taking up the slack of the depression years and without considering equipment to be retired because of age or depreciation.

The present generating capacity of private and public electric generating plants, including both steam and hydro, is stated to be close to $34^1/_2$ million kilowatts. A recent statistical analysis from one utility source estimates the 1937 requirements to be 36,620,000 kilowatts, those for 1938 as 39,020,000 kilowatts and those for 1939 as 42,020,000 kilowatts. If these estimates be anywhere near correct, a shortage in total capacity becomes apparent during the next three years, despite present construction and a somewhat improved use factor.

Central Heating Prospects

Present activity in steam plant construction to meet increased electrical demands seems to have overshadowed the possibilities that may lie ahead of the central steam heating industry. An almost negligible part of the present construction will serve that field.

While expansion of electric generating facilities must keep pace with increased industrial production and public needs, the expansion of central heating service depends upon other factors, such as increased building construction, wider acceptance of its advantages and convenience and, in the case of new systems, the availability of interested capital for development of the necessary facilities.

There are strong indications that the next two years will see a revival of building construction and it remains to make the public "steam-minded" just as it has been made "electrical-minded." In so far as domestic consumers are concerned, the two cases are not strictly comparable; for, obviously, it would be uneconomical to extend steam service to other than concentrated areas. However, apartment house groups and slum clearance projects, as well as office buildings, provide an attractive class of customers, especially as the increasing popularity of air conditioning affords a means of attaining higher annual load factors.

If the present rise in industrial activity is followed by a building boom, as many predict, one may expect a substantial extension of central heating service for which additional steam generating capacity will be required.

Trends and Developments in Industrial Turbines

By E. R. KAUFFMAN, Turbine Division, Westinghouse Elec. & Mfg. Co.

A review of the industrial turbine construction during the past few years discloses the rather significant fact that this activity did not decrease to the same extent as other major lines during the period of low general activity. In units of moderate size, such as are usually found in industrial service, the thermal efficiency of the straight condensing plant may be approximately 26 per cent. However, if all of the electrical energy is developed by non-condensing units, in which the exhaust steam is used for heating or process work, a thermal efficiency of 73 per cent is possible. This ideal condition is, of course, never maintained in practice, but a large proportion of the gain can be obtained by the use of non-condensing and extraction machines, typical units of which are described.

WHILE the manufacturers, by research and development work, have gone far in making available to industries a great variety of types of machines, industry itself shows the real trend by the machines which it purchases. Practically all of these turbines are tailor-made. Standard parts are used to the maximum possible extent, but in the final analysis, each machine must be designed and built to fit into the particular plant for which it is intended.

The following types of turbines, rightly called "Industrial Turbines," are ideal for either modernizing old plants or for complete new installations where steam is required for heating or process work:

1. Single extraction, condensing turbines.
2. Double extraction, condensing turbines.
3. Non-condensing turbines.
4. Single extraction, non-condensing turbines.
5. Extraction and/or induction turbines (either condensing or non-condensing).
6. Mixed-pressure turbines.

Fig. 1 shows a longitudinal section of a 7500-kw, single extraction, condensing turbine. This machine operates with steam conditions of 625 lb gage 725 F and 27½ in. vacuum, extracting at 110 lb gage. It is of the Curtis and reaction type, the blade path consisting of a Curtis stage and six pairs of reaction rows between the inlet and the extraction point, and a Curtis stage followed by twelve pairs of reaction rows between the extraction point and the exhaust.

Fig. 2 is a similar view of a 6000-kw, single-extraction, non-condensing machine which operates with steam conditions of 400 lb gage 700 F and 3 lb gage back pressure, extracting at 150 lb. The blade path consists of a Curtis element followed by reaction blading between the inlet and the extraction point and a Rateau element followed by reaction blading between the extraction point and the exhaust.

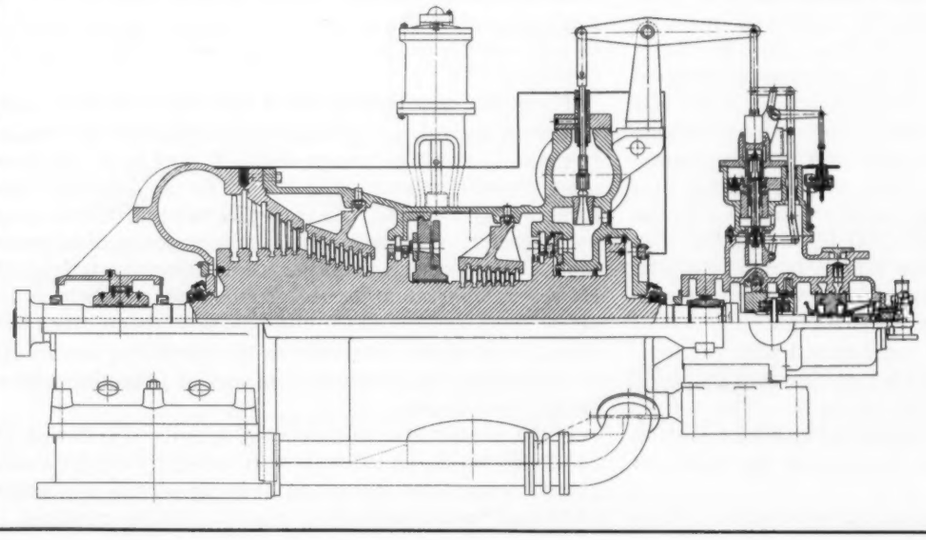


Fig. 1—Cross-section of 7500-kw, single-extraction, condensing turbine containing both Curtis and reaction stages

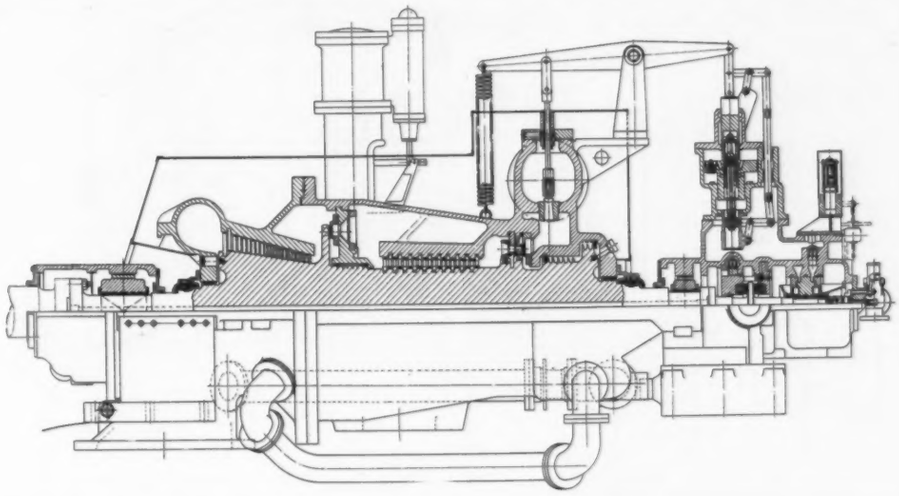


Fig. 2—Cross-section of 6000-kw, single-extraction, non-condensing turbine employing Curtis, reaction and Rateau elements

Fig. 3 represents a 2500-kw, straight non-condensing machine built for steam conditions of 560 lb gage 700 F and 200-lb back pressure. It is of the Curtis and reaction type, the blade path consisting of a single Curtis stage followed by seventeen pairs of rows of reaction blades.

Fig. 4 shows a 1160-hp non-condensing turbine. The steam conditions are: 210 lb gage 515 F steam temperature and 35-lb back pressure. This machine is of the Curtis and Rateau types, the blade path consisting of one Curtis stage followed by four Rateau stages.

Trend toward Higher Ratings

These turbines can be built for practically any capacity desired. In the double-extraction type with ratings above 7500 kw, a two-cylinder tandem construction gives the best arrangement. With this exception, they are all of the single-cylinder type and operate at 3600 rpm. As shown by the units built, there is a decided trend toward higher ratings. Of those units built since January 1, 1936, approximately one-fourth are of 5000-kw rating or higher.

These units have been developed for inlet steam conditions up to 1400 lb and a maximum of 950 F total steam temperature. The design can be arranged for practically any exhaust pressure required. It is desirable to utilize the maximum inlet steam conditions which are compatible with other plant requirements in order to realize the greater thermodynamic gain.

However, the use made of process steam and its pressure are the major factors which determine the inlet steam conditions. In practically all cases, superheated steam in the process line is undesirable, the ideal condition being dry and saturated. The most suitable inlet conditions are, therefore, those which will give dry and saturated steam in the process line. Hence, the inlet conditions are governed by the rating of the unit and the pressure drop between the inlet condition and the process line. It is seldom for such service that inlet steam conditions higher than 600 lb pressure and 750 F total temperature can be justified. The increase to these approximate conditions has been rapid. Many of the units built during the past year have been for pressures and temperatures of this order. Likewise the extraction pressures have increased greatly. As recently as ten years ago, 400 lb was considered a high inlet pressure but during the past year, one machine was placed in service extracting at 400 lb and many units are operating with extraction pressures of 100 to 200 lb gage.

Construction Details

Cylinder construction has been improved to meet the requirements associated with the higher steam temperatures. In Westinghouse turbines blade ring elements are separate from the cylinder proper and are supported on keys at the horizontal centerline with pins at top and bottom to maintain correct alignment, thus minimizing the possibility of cylinder distortion affecting the steam carrying elements.

Many of the industrial applications operate non-condensing. Hence, the method of supporting this type of unit is of great importance. The non-condensing turbine cylinders are supported by arms cast integrally at the top of the base, thus locating the points of support as closely as possible to the horizontal center line. On the high-temperature machines, these arms rest on pedestals which are separate from the cylinder, thereby obtaining the advantages of relatively cooler supports for the bearings. At the coupling end, keys between the cylinder arms and the pedestal allow free transverse movement but anchor the cylinder in an axial direction, while a key on the vertical centerline maintains the correct alignment in a transverse direction. At the inlet end, the cylinder arms are likewise keyed to the pedestal which in turn is free to slide on its base, thus allowing free movement in an axial direction. At this end also, transverse alignment is maintained by keys on the vertical centerline.

The steam chests are located at the top of and cast integrally with the cylinder cover. This construction eliminates one steam joint and reduces to a minimum the entrapped steam between governing valves and the nozzles. Furthermore, it eliminates all interconnecting piping between the steam chest and cylinder, thereby decreasing the possibility of strains in the piping causing cylinder distortion.

Blade construction has been improved, the most notable features tending toward sturdier construction and hence greater reliability. "T"-root fastenings are used

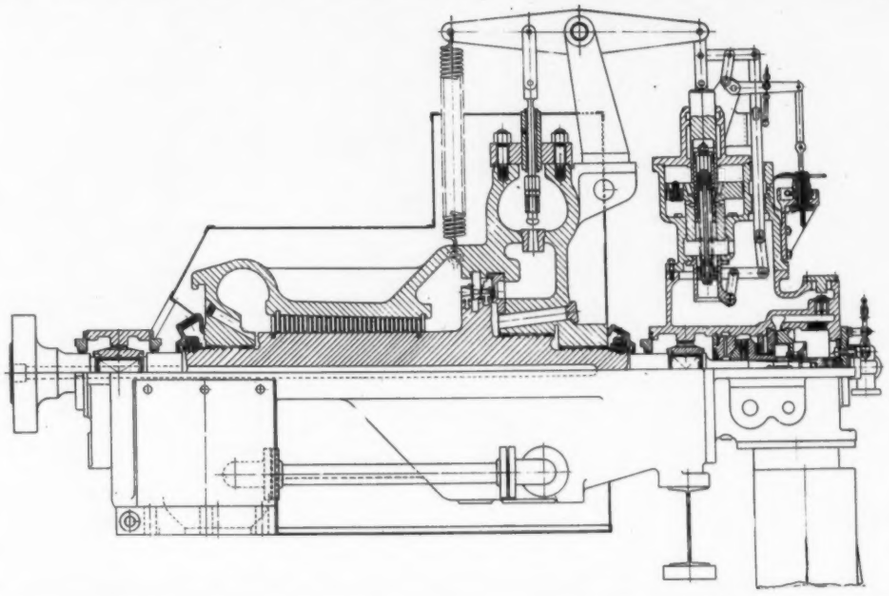


Fig. 3—Straight non-condensing turbine with one Curtis stage and seventeen rows of reaction blading, built for 200-lb back pressure

throughout. In those portions of the turbine where steam leakage around the blade tips is of importance, the blades are shrouded and labyrinth seals are used between the shroud and the adjacent parts.

A new sealing arrangement has been developed and is now being applied in all cases where labyrinth seals are required. This arrangement consists of thin flat strips which are secured in the grooves by soft steel strips rolled into place. With this arrangement, the massive rotating and stationary parts are separated by relatively large clearances and the small clearances are maintained by these thin seal strips. The strips are made of a special alloy material with excellent wearing qualities and if contact should occur the strips wear away without resulting in any damage to major parts.

Hydraulic Control

A feature which differentiates an industrial turbine from the average prime mover is its control system. Since practically all of these machines involve extraction pressures, back pressures and electrical frequency which must be maintained constant, within reasonably close limits, the control system becomes a most important factor in successful operation.

The Westinghouse governors are of either of two general classes. On the smaller machines, a vertical flyball

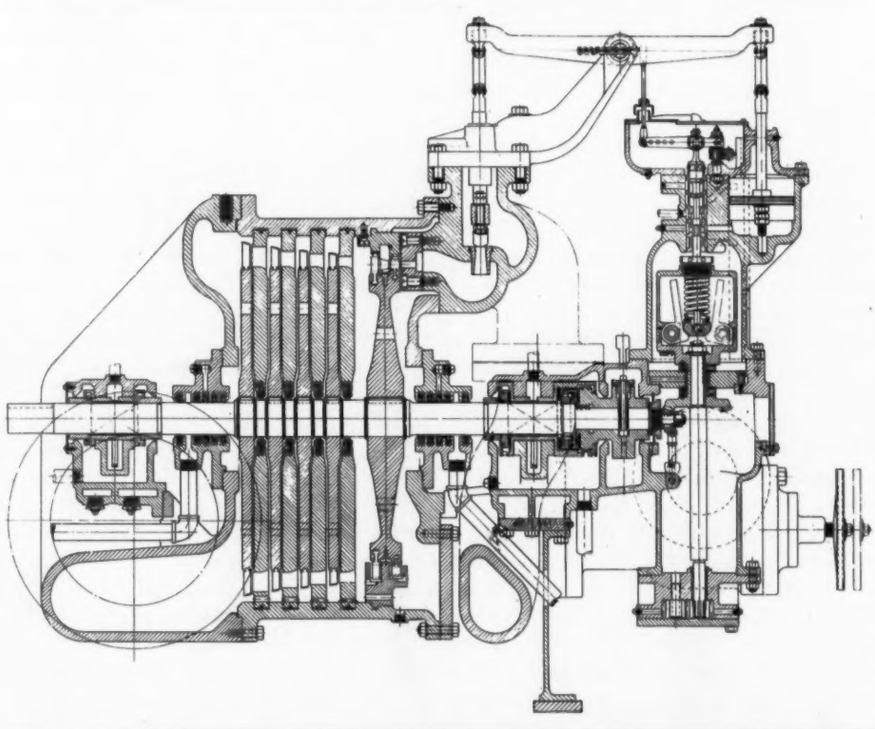


Fig. 4—A non-condensing turbine with one Curtis and four Rateau, stages, built for 35-lb back pressure

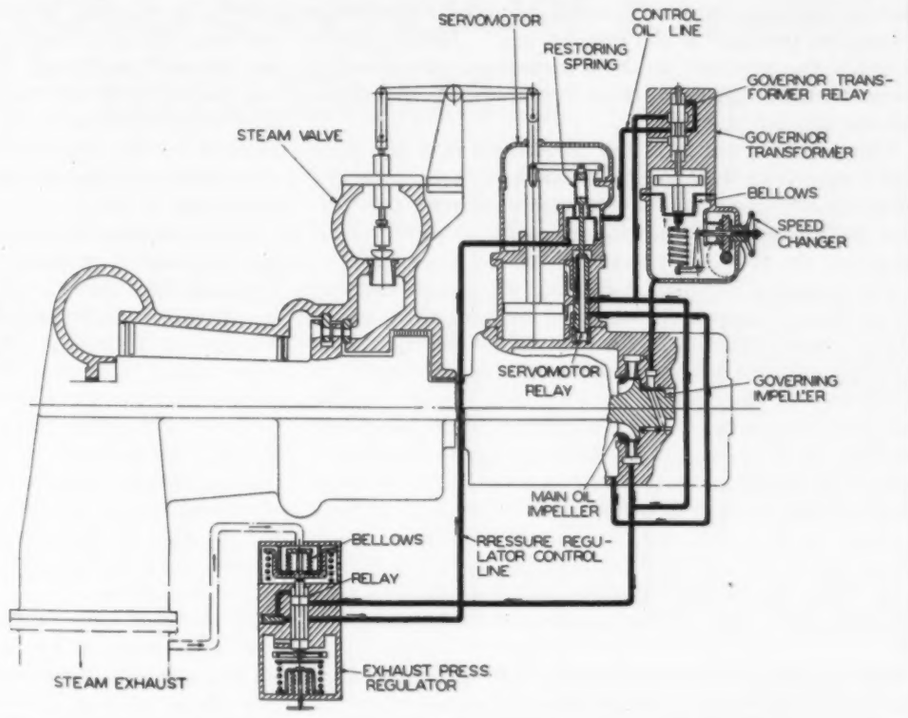


Fig. 5—Control diagram of non-condensing turbine employing an exhaust pressure regulator

governor, is used in conjunction with a fluid pressure transformer and a servo-motor which supplies ample power for valve operation. On the larger machines a full hydraulic governor is used. The same type as has been used successfully for years past is still a standard feature. For those machines requiring the ultimate in control, a new pressure-transformer type of governor, identical with that used on large central station turbines, is applied.

The extraction mechanisms are all of the same general type. The pressure in the extraction line is maintained constant, within reasonably close limits, by a grid-type extraction valve which is located in the cylinder and controls the flow of steam toward the exhaust, thus maintaining in the cylinder zone on the high-pressure side of the extraction valve, that pressure which is desired in the extraction system. This extraction valve is opened or closed by a hydraulic servo-motor which is actuated by the extraction-pressure regulator.

Other parts of the control system, include extraction-pressure regulators, exhaust-pressure regulators and governor compensators. All of these devices are hydraulically operated and are connected to other parts of the system by pipe lines only, thus eliminating mechanical linkage. These control systems necessarily become somewhat complicated and descriptions of the many various arrangements which are possible cannot be given here. The following, however, show the most commonly used arrangements.

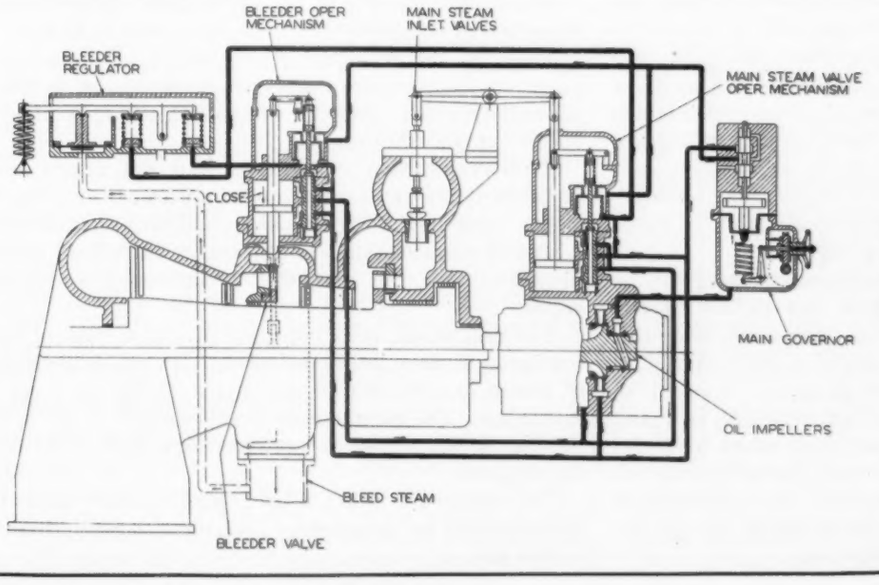


Fig. 6—Diagram of a pressure-compensated extraction control system in which the extraction pressure regulator is of the direct-acting type

Fig. 5 shows the control diagram of a non-condensing turbine, using an exhaust-pressure regulator to maintain a constant pressure in the exhaust line. This regulator actuates the governor so as to increase or decrease the steam flow through the turbine in response to changes in exhaust steam demand.

The governor shown in the illustration is of the pressure-transformer type which consists of three principal parts, namely, a reverse flow impeller attached to the turbine shaft, a pressure transformer and a servo-motor for operating the governor valves.

The governor impeller, consisting of a single inclined hole in the rotating shaft, delivers a pressure which varies as the square of the turbine speed. Hence changes in this discharge pressure are an accurate measure of changes in rotative speed and provide the governing impulses to the pressure transformer. The transformer multiplies these pressure changes so that the total change in fluid pressure available for operation of the servo-motor relay is relatively large, thus insuring positive action. A conventional type of impeller, driven by the turbine shaft (as shown at the left of the governing impeller), serves as the main oil pump and supplies high pressure oil to the governing valve servo-motor and exhaust-pressure regulator.

This exhaust-pressure regulator is, likewise, of the pressure-transformer type in which changes in exhaust steam pressure actuate an oil relay, thus converting steam-pressure changes into oil-pressure changes, which in turn, actuate the governing valve servo-motor. With an increase in exhaust pressure, the regulator causes the govering valves to close slightly, and vice versa. Hence, the steam flow through the turbine is regulated according to the exhaust steam demand. Needless to say, with this arrangement, the electrical load carried depends entirely on the demand for exhaust steam and the unit must operate in parallel with some other source of electrical power.

Fig. 6 shows a diagram of a pressure-compensated, extraction-control system. This governor is of the same type described above. The extraction-pressure regulator is of the direct-acting type in which changes in extraction pressure actuate two small relief valves. The relief valve on the right controls the oil pressure acting on the extraction valve servo-motor and the one on the left controls the oil pressure acting on the governing valve servo-motor. An increase in extraction pressure causes the extraction valve to open and at the same time causes the governing valves to close sufficiently to compensate for the decrease in extracted steam demand. With a decrease in extraction pressure, the valves move in the opposite directions.

By means of a simple adjustment on the pressure-transformer governor, or by the addition of a speed compensator to the older type of hydraulic governor, the regulation can be made as close as desired, even to the point of isochronous operation. This feature is of utmost importance in some industrial processes.

Johns Hopkins Engineering School to Celebrate Twenty-Fifth Anniversary

Prominent engineers from other colleges and from the industrial field will participate in the twenty-fifth anniversary celebration of the Johns Hopkins School of Engineering to be held February 19 to 22. An address by Dr. Karl T. Compton, president of the Massachusetts Institute of Technology, to be delivered at the sixty-first Commemoration Day exercises of the University on February 22, will be the high-light of a program planned to include special technical sessions and an extensive exhibition of industrial and research projects.

With a view to recognizing important progress over the entire range of engineering development, each of the several departments of the Hopkins School will display representative models, devices and processes. Dr. Wilbert J. Huff, professor of gas engineering and nationally prominent in his field, is supervising arrangements for a demonstration of the combustion of gases and the apparatus used in testing them.

Included in this phase of chemical engineering will be a demonstration of the melting of soft metals by the use of immersion burners, and a gas flame will be shown burning under water. Much material of interest will be afforded by the exhibition of new processes invented by research groups, especially that for removing sulphur compounds from commercial gases at elevated temperatures. Experiments in the burning characteristics of gases, the analysis of oils and gasoline, the evaluation of iron oxides for gas purification and methods for the recovery of by-products may be observed.

Also on view will be a model of a coke oven battery; the working parts of a gas refrigerator; the apparatus for distilling coal and for examining tar, oils and gas; and novel forms of gas analysis apparatus developed at the Hopkins School.

Papers by the principal members of the faculty are to be read at the morning conference sessions on February 20. Dean J. B. Whitehead, first professor of electrical engineering, upon the opening of the School in 1912, has arranged to invite officials of the State and City, leading industrial engineers and many research specialists from other colleges to take part in the technical discussions.

Additional features of the exhibition related to other branches of engineering investigation will include:

Tests on the dielectric properties of oil-impregnated paper for high-tension cables; experiments on oxidation in insulating oils; and the effect of lightning on modern power transmission lines.

A demonstration of stresses and deflections on a radically new type of tubular steel piles for bridge foundations; experiments on the flow and pumping of water; actuated dioramas of slum clearance and flood control projects; and the magnetic investigation of electric welds.

The first public demonstration of a new form of bearing based on pure fluid lubrication; the physical changes of steam in a turbine nozzle made visible in a special apparatus; the most recent developments in air conditioning, steam vapor jet refrigeration and automotive diesel power.

The twenty-five years of the School's history have been characterized by progressive investigation and advanced instruction.

CENTRAL STATION FLOW DIAGRAMS

IN THE following pages of this section are shown flow diagrams of some of the recent high-pressure installations in central stations. It is believed that this collection will serve as a convenient reference. Space does not permit detailed descriptions and the paragraphs below merely give a few high spots of these installations. A subsequent issue will contain additional diagrams.

LOGAN STATION

There is now being installed at the Logan (W. Va.) Station of the Appalachian Electric Power Company a 1,000,000-lb per hr, double-set, bent-tube boiler with economizers and regenerative type air heaters, designed for steam conditions of 1400 lb pressure and 925 F total steam temperature. The unit is direct-fired with pulverized coal, and has a dry-bottom type of furnace. It will supply steam at 1325 lb to a 50,000-kw, 3600-rpm turbine-generator, exhausting to the existing low-pressure turbines in that station.

WATERSIDE STATION

Four 500,000-lb per hr sectional-header boilers, and two 50,000-kw, 3600-rpm high-pressure turbine-generators constitute the initial superposed installation at the Waterside Station of the New York Edison Company. The flow diagram shown herewith covers only two of these units. These boilers are of the cross-drum sectional-header type, designed for 1400 lb pressure (1325 lb at the superheater outlet) and 900 F total steam temperature. Tangential firing and continuous slagging furnaces will be employed, and each unit will be served by two bowl-type mills. Both economizers and air heaters of the regenerative type are included. The high-pressure units will exhaust to existing low-pressure turbines in Waterside No. 1, although a portion of the 200 lb exhaust will be used to heat the feedwater of the high-pressure boilers.

12th STREET STATION, RICHMOND, VA.

The Virginia Electric and Power Company has recently installed a superposed high-pressure boiler and turbine at its 12th Street Station. This boiler is of the bent-tube type, designed for a maximum output of 450,000 lb per hr at 860-lb operating pressure, and 835 F total steam temperature. It is tangentially fired with pulverized coal and has a slagging furnace. Steam is supplied to a 12,500-kw turbine-generator which exhausts at 220-lb back pressure to the existing low-pressure units.

FISK STREET STATION

Two new high-pressure boilers and a 30,000-kw turbine-generator are being superposed on the old low-pressure equipment at the Fisk Street Station of the Commonwealth Edison Company in Chicago. The boilers are of the straight-tube sectional-header type, each rated at 412,500 lb per hr maximum, at 1275-lb working pressure, and 910 F total steam temperature. They are fired with pulverized coal and have slagging furnaces.

PORT WASHINGTON STATION

The Port Washington Station of the Milwaukee Electric Light and Railway Company has been in operation a little over a year and has the distinction not only of being the most efficient central station in the world but also of being the only large station with a single boiler and single turbine-generator. The boiler is rated at 690,000 lb of steam per hr and is designed for 1390 lb pressure.

MILLER'S FORD STATION

At the Miller's Ford Station of the Dayton Power and Light Company there is being put in a superposed installation consisting of two single-pass, cross-drum, sectional-header boilers of 375,000 lb per hr maximum capacity each. They are designed for 1350 lb pressure and 900 F total steam temperature, and will furnish steam to a 25,000-kw, 3600-rpm turbine-generator exhausting at 230 lb to the low-pressure units. The boilers will be direct fired with pulverized coal and have water-cooled, hopper-bottom furnaces. Both air heaters and economizers are provided.

NORTHEAST STATION

At the Northeast Station of the Kansas City Power and Light Company a 300,000-lb per hr, 1400 lb pressure, 915 F, straight-tube cross-drum boiler is being installed to supply steam to an existing high-pressure turbine which exhausts through reheaters to the low-pressure equipment in the station. The new unit is capable of supplying all the steam required by this turbine at its rated capacity or, in combination with one of the existing high-pressure boilers, it will produce 25 per cent overload. It also serves as reserve capacity for the station. It is tangentially fired with pulverized coal, furnished by bowl-type mills and has an economizer and two regenerative-type air heaters.

SPRINGDALE STATION

The West Penn Power Company is installing in its Springdale Station three 1450-lb, 935 F, sectional-header cross-drum, pulverized-coal-fired boilers of 500,000 lb per hr each, to supply a high-pressure turbine-generator. The boilers will be direct-fired and have continuous slagging furnaces designed for high load factor operation. Both economizers and air heaters are installed.

STATION NO. 3, ROCHESTER

The superposed high-pressure extension to Station No. 3 of the Rochester Gas and Electric Corporation consists of two 250,000-lb per hr, bent-tube boilers designed for operation at 650 lb pressure, 750 F total steam temperature. One of these units is now in operation and the other on order. These are each laid out to supply a 6000-kw non-condensing turbine-generator exhausting to existing 200 lb low-pressure units. Pulverized coal is employed with a dry-bottom furnace and economizers are included.

OMAHA STEAM STATION

The high-pressure extension to this station of the Nebraska Power Company consists of a 275,000-lb per hr bent-tube boiler designed for 1350 lb pressure, 910 F total steam temperature and fired by a 569-sq ft chain-grate stoker. The unit has an economizer and a regenerative type air heater. It supplies steam to a 12,500-kw turbine-generator which exhausts to the low-pressure units.

MONTVILLE STATION

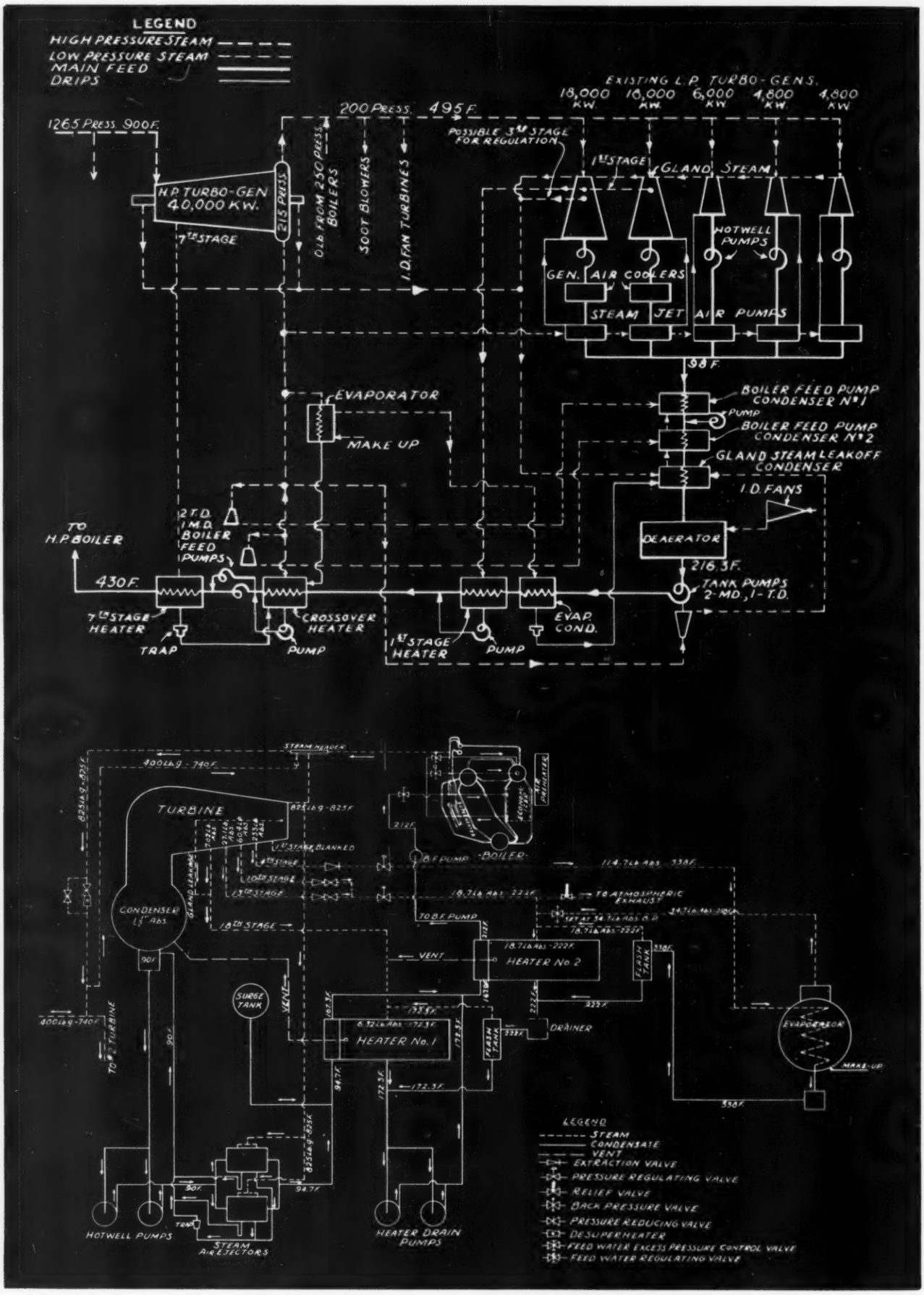
This Station of the Connecticut Light and Power Company is being extended by the addition of two 130,000-lb per hr, three-drum, bent-tube boilers, designed for 725 lb pressure (650 lb at the superheater outlet), and a total steam temperature of 825 F. Each boiler will be served by two bowl mills and will have a regenerative type air heater. This is not a superposed installation inasmuch as the boilers will supply a 25,000-kw condensing turbine-generator.

RIVERSIDE STATION

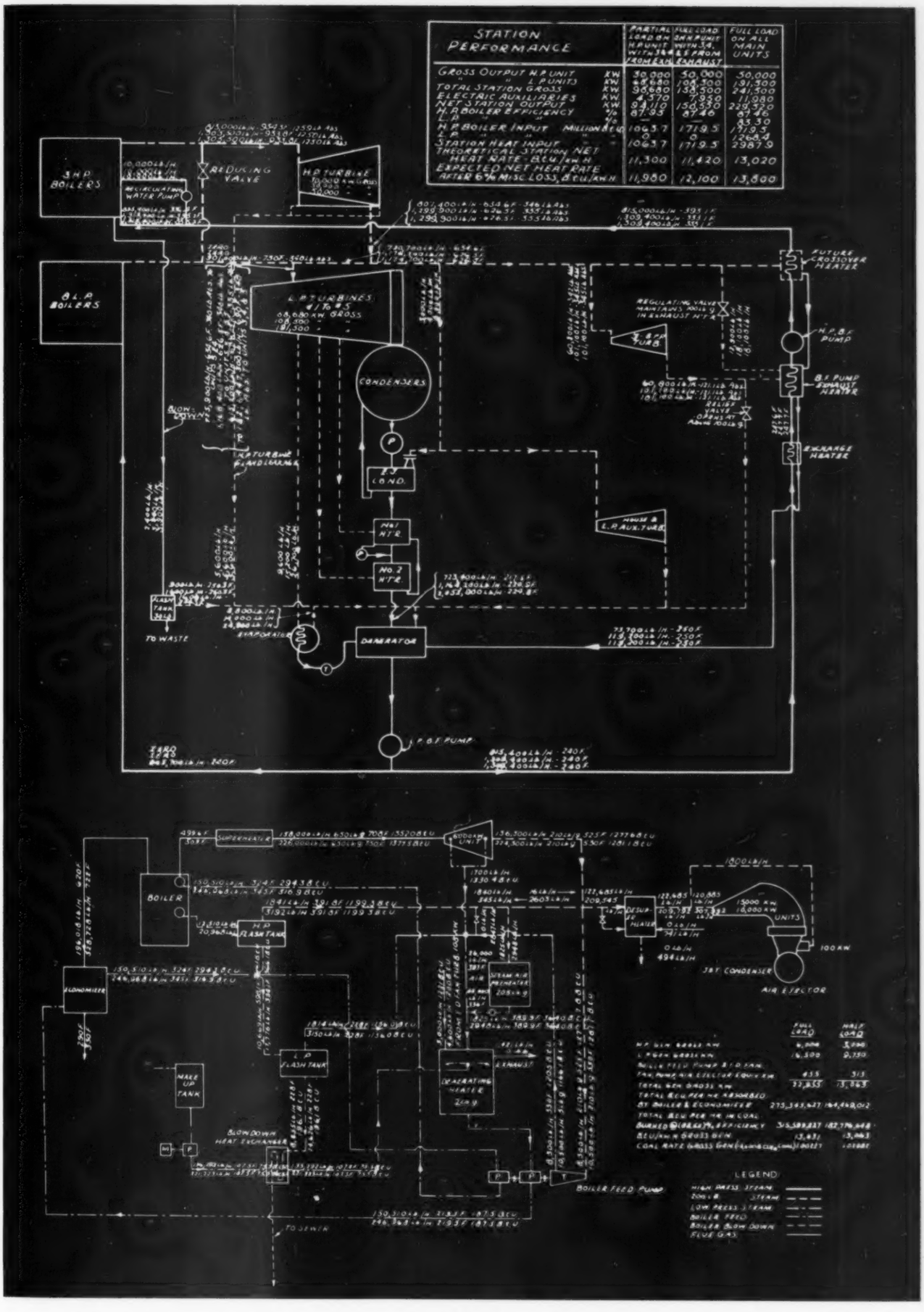
The United Power Manufacturing Company is adding a high-pressure unit to its Riverside Station at Iowana, Ia. (near Davenport). This is not superposed in that the new 300,000-lb per hr bent-tube boiler supplies steam at 825 lb pressure, 825 F steam temperature to a high-pressure condensing turbine and, also through reducing valves, steam at 400 lb to an existing turbine. The boiler is pulverized-coal fired, being served by three bowl mills and has both an economizer and a regenerator-type air heater.

CONNERS CREEK STATION

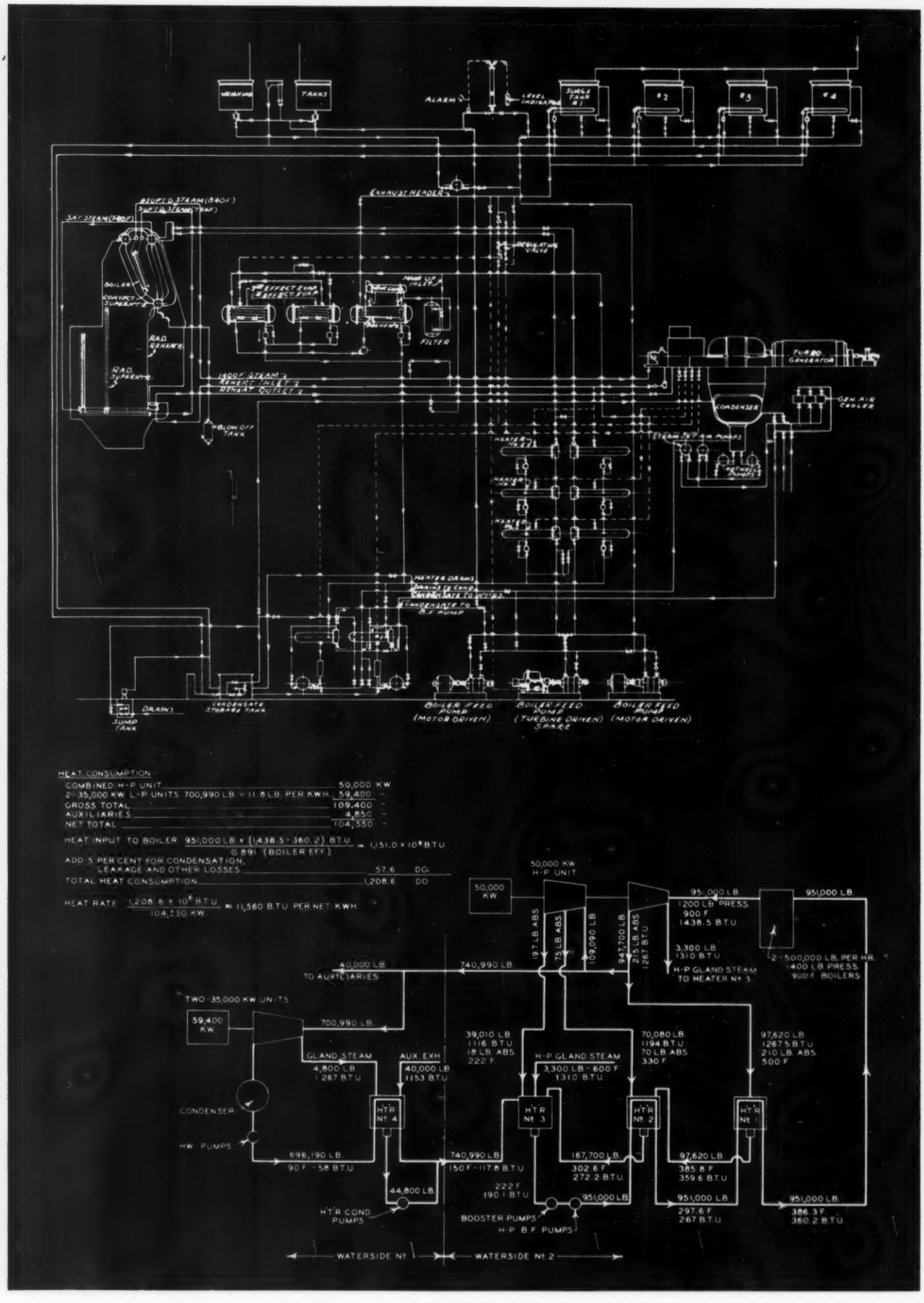
The Conners Creek Station of the Detroit Edison Company, which has been undergoing progressive rebuilding during the past two years, employs a straight regenerative cycle, stoker firing, steam conditions of 710 lb, 850 F, and turbine-generating units of 30,000 and 60,000 kw. The boilers are of the bent-tube double-set type, each rated at 420,000 lb of steam per hr maximum.



Upper diagram—Logan Station, high-pressure extension
Lower diagram—Riverside Station, Iowana, Ia.



Upper diagram—Springdale Station, Pittsburgh, with 50,000-kw high-pressure addition
Lower diagram—Station No. 3, Rochester, full and half-load flow



HEAT CONSUMPTION

COMBINED H-P UNIT	50,000 KW
2-35,000 KW L-P UNITS 700,990 LB ÷ 11.8 LB. PER KWH	59,400 "
GROSS TOTAL	109,400 "
AUXILIARIES	4,850 "
NET TOTAL	104,550 "

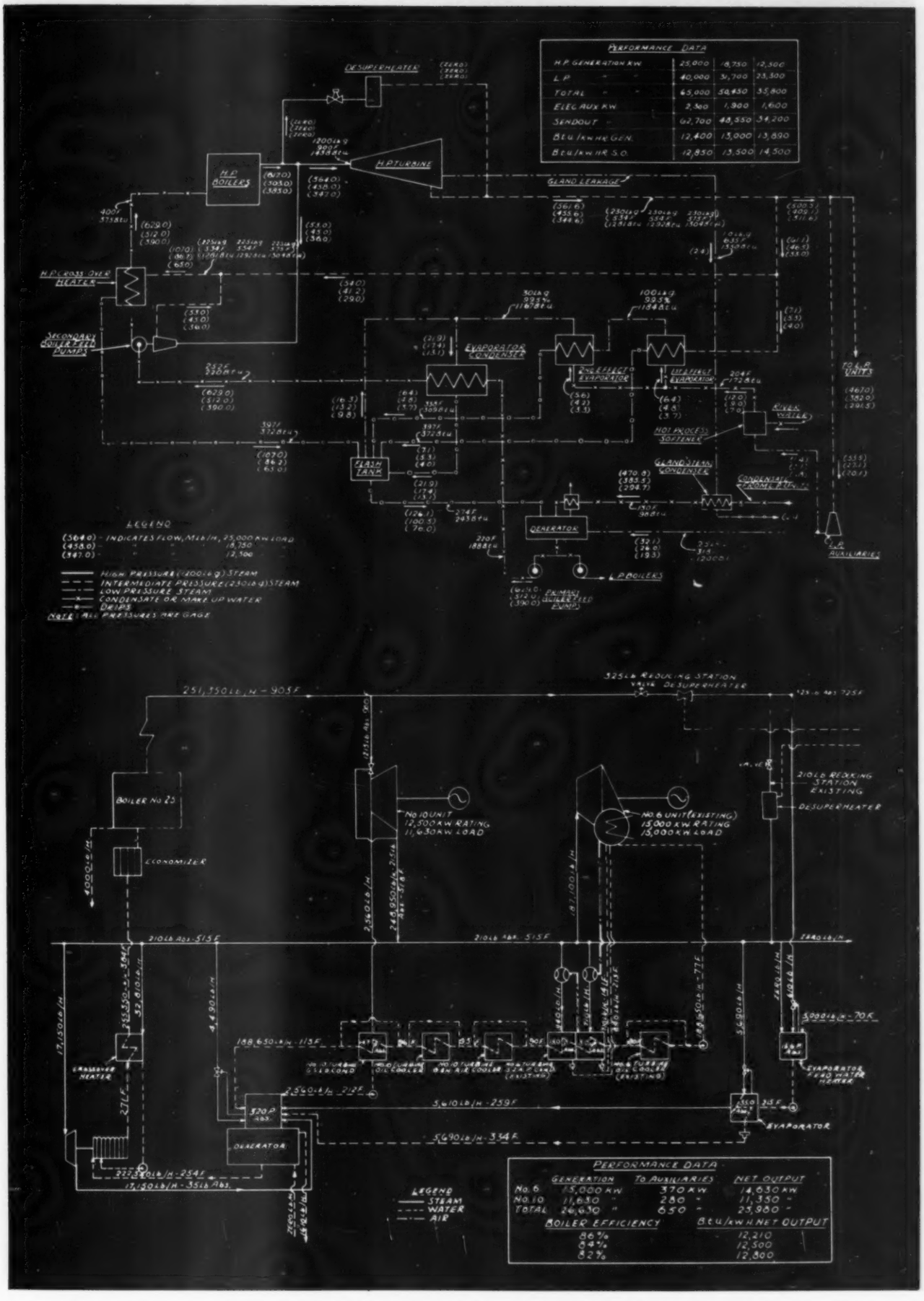
HEAT INPUT TO BOILER $\frac{951{,}000 \text{ LB} \times (1438.5 - 360.2) \text{ B.T.U.}}{0.891 \text{ (BOILER EFF.)}} = 1{,}151.0 \times 10^6 \text{ B.T.U.}$

ADD 5 PERCENT FOR CONDENSATION, LEAKAGE AND OTHER LOSSES	57.6	DO.
TOTAL HEAT CONSUMPTION	1,208.6	DO

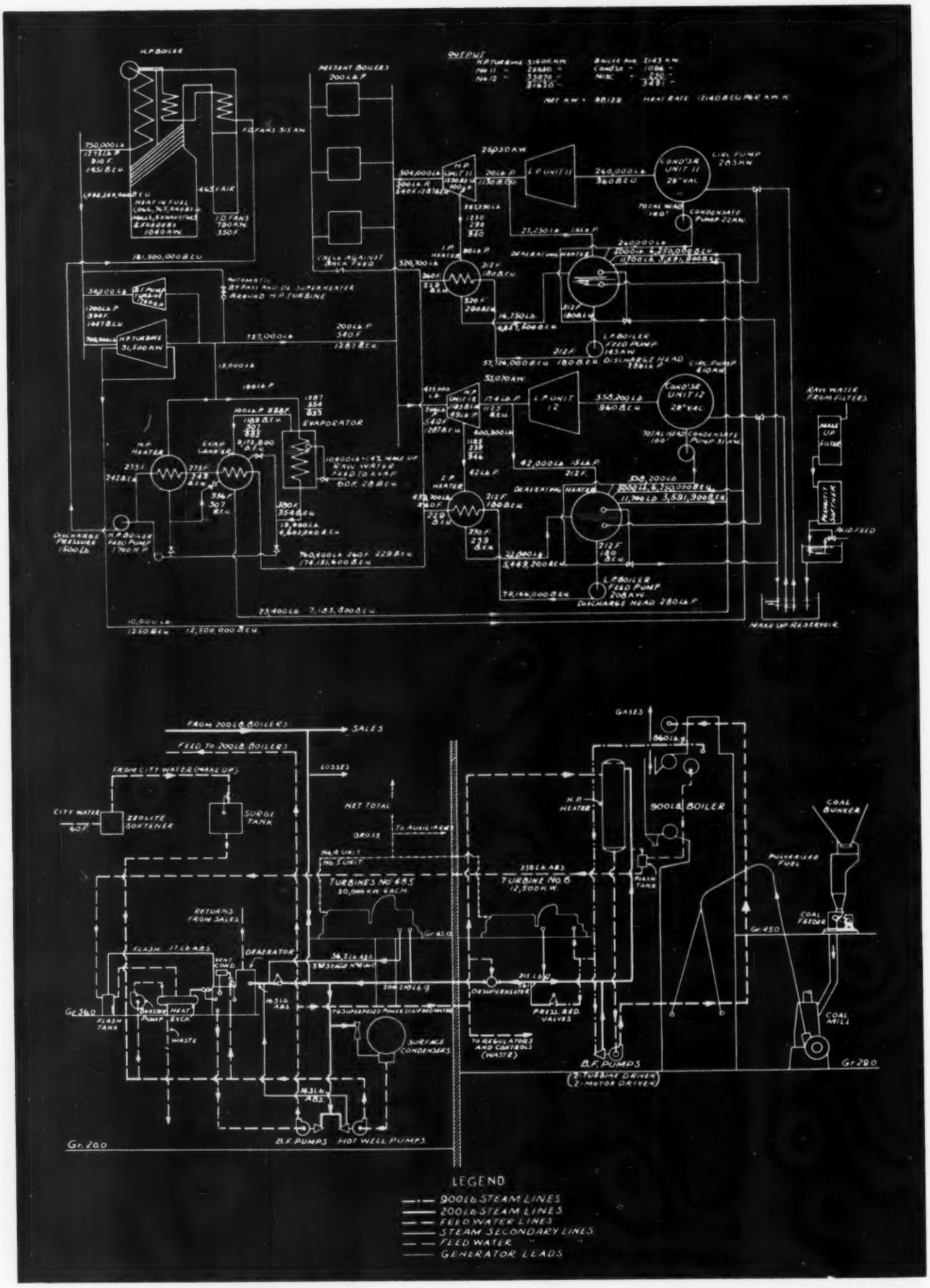
HEAT RATE $\frac{1{,}208.6 \times 10^6 \text{ B.T.U.}}{104{,}550 \text{ KW.}} = 11{,}560$ B.T.U. PER NET KWH

50,000 KW H-P UNIT
50,000 KW.
19.7 LB. ABS.
75 LB. ABS.
109,090 LB.
947,700 LB.
215 LB. ABS. 1267 B.T.U.
95,000 LB. 1200 LB. PRESS. 900 F. 1438.5 B.T.U.
951,000 LB.
3,300 LB. 1310 B.T.U. H-P GLAND STEAM TO HEATER No. 3
2-500,000 LB. PER HR. 1400 LB. PRESS. 900 F. BOILERS
40,000 LB. TO AUXILIARIES
740,990 LB.
TWO-35,000 KW UNITS
59,400 KW.
700,990 LB.
GLAND STEAM 4,800 LB. 1267 B.T.U.
AUX. EXH. 40,000 LB. 1153 B.T.U.
39,010 LB. 1116 B.T.U. 18 LB. ABS. 222 F.
H-P GLAND STEAM 3,300 LB. - 600 F. 1310 B.T.U.
70,080 LB. 1194 B.T.U. 70 LB. ABS. 330 F.
97,620 LB. 1267.5 B.T.U. 210 LB. ABS. 500 F.
CONDENSER
H.W. PUMPS
HTR No. 4
HTR No. 3
HTR No. 2
HTR No. 1
696,190 LB. 90 F. - 58 B.T.U.
740,990 LB. 150 F. - 117.8 B.T.U.
167,700 LB. 302.6 F. 272.2 B.T.U.
97,620 LB. 385.8 F. 359.6 B.T.U.
951,000 LB. 386.3 F. 360.2 B.T.U.
44,800 LB.
222 F. 190.1 B.T.U.
951,000 LB.
951,000 LB. 297.6 F. 267 B.T.U.
HTR COND. PUMPS
BOOSTER PUMPS
H-P B.F. PUMPS
WATERSIDE No. 1
WATERSIDE No. 2

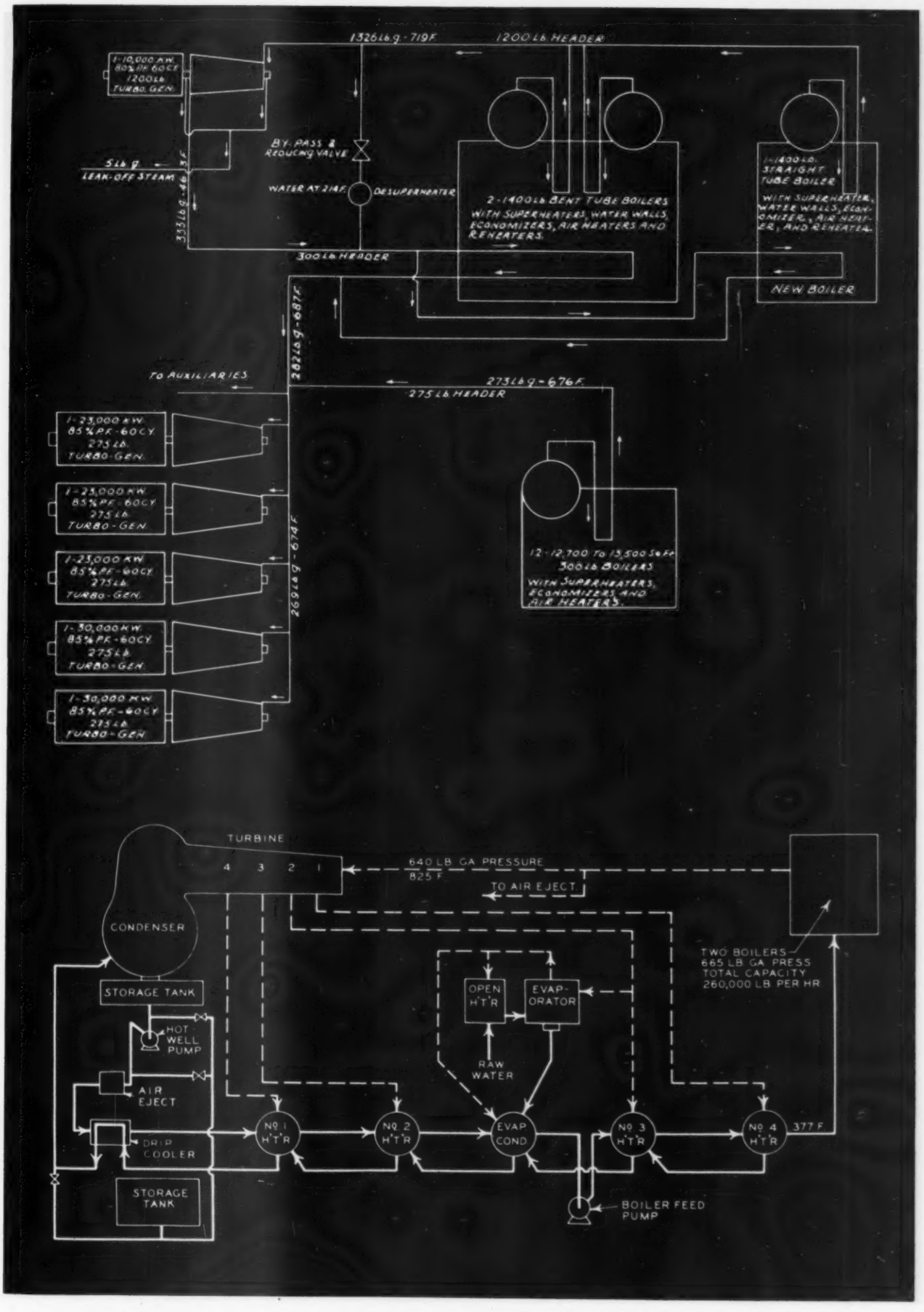
Upper diagram—Port Washington Station; basic flow diagram
Lower diagram—Waterside No. 2, New York; for one 50,000-kw turbine and two-boilers



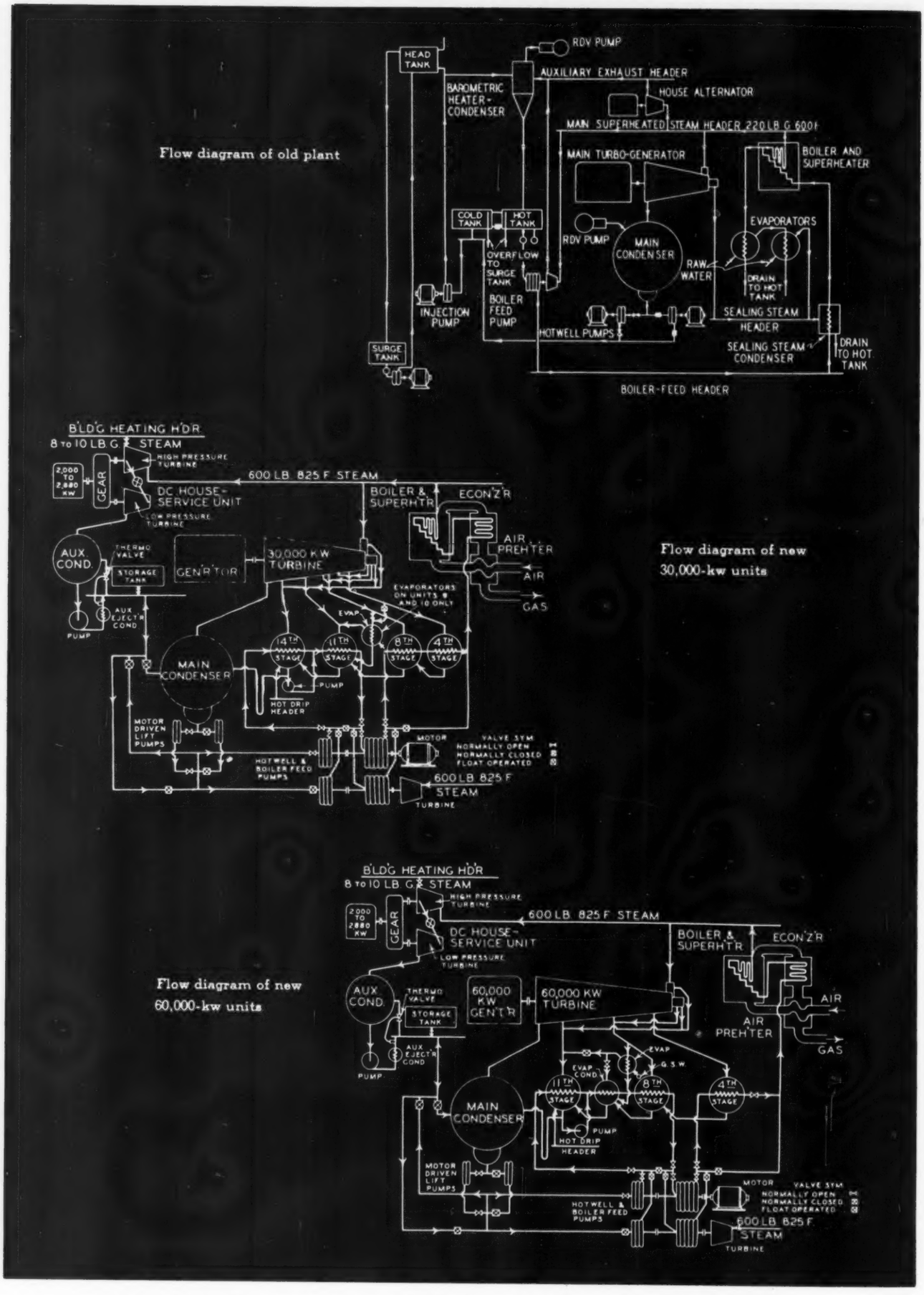
Upper diagram—Miller's Ford Station, Dayton, O.; high-pressure extension
Lower diagram—Omaha Station; 12,500-kw high-pressure extension



Upper diagram—Fisk Street Station, Chicago; high-pressure extension
Lower diagram—12th Street Station, Richmond, Va.; 860-lb. superposed extention


1326Lbs - 719F
1200 Lb HEADER
1-10,000 KW. 85% PF 60 CY 1200 Lb TURBO-GEN.
BY-PASS & REDUCING VALVE
51 Lbs
LEAK-OFF STEAM
335Lbs - 446F
WATER AT 21AF
DESUPERHEATER
2-1400 Lb BENT TUBE BOILERS WITH SUPERHEATERS, WATER WALLS, ECONOMIZERS, AIR HEATERS AND REHEATERS.
1-1400 Lb. STRAIGHT TUBE BOILER WITH SUPERHEATER, WATER WALLS, ECONOMIZER, AIR HEATER, AND REHEATER.
300 Lb HEADER
NEW BOILER
282Lbs - 687F
TO AUXILIARIES
273Lbs - 676F
275 Lb HEADER
1-23,000 KW. 85% PF - 60 CY. 275 Lb. TURBO-GEN.
1-23,000 KW. 85% PF - 60 CY. 275 Lb. TURBO-GEN.
1-23,000 KW. 85% PF - 60 CY. 275 Lb. TURBO-GEN.
1-30,000 KW. 85% PF - 60 CY. 275 Lb. TURBO-GEN.
1-30,000 KW. 85% PF - 60 CY. 275 Lb. TURBO-GEN.
269Lbs - 674F
12-12,700 TO 13,500 Sq Ft 300 Lb BOILERS WITH SUPERHEATERS, ECONOMIZERS AND AIR HEATERS.
TURBINE
4 3 2 1
640 LB GA PRESSURE
825 F
TO AIR EJECT.
CONDENSER
STORAGE TANK
HOT WELL PUMP
AIR EJECT
DRIP COOLER
STORAGE TANK
OPEN H'T'R
EVAP-ORATOR
RAW WATER
TWO BOILERS 665 LB GA PRESS TOTAL CAPACITY 260,000 LB PER HR
Nº 1 H'T'R
Nº 2 H'T'R
EVAP COND
Nº 3 H'T'R
Nº 4 H'T'R
377 F
BOILER FEED PUMP

Upper diagram—Northeast Station, Kansas City; new 1400 lb boiler
Lower diagram—Montville Station; 25,000-kw condensing unit



Flow diagrams for Conners Creek Station of the Detroit Edison Co.

Design of High-Pressure Boilers*

By E. LUPBERGER, Berlin

The author reviews German practice as pertains to details of design, such as the substitution of small tubes for those of larger diameter entering drums, the use of ferrules for increasing the adhesion of rolled-in tubes, and superheater connections. He also discusses circulation, air and gas flow, the separation of water and steam, and compares several typical high-pressure boiler designs. Reference is made to the recently prescribed standardization of steam conditions and the pending standardization of unit capacities and of certain boiler parts.

ONLY a few years ago it was a mark of personal inclination, receptiveness to engineering progress and readiness to accept responsibility, if the man in charge of building a new power plant considered the employment of high-pressure steam of around 1500 lb or more. It was the period of pioneers. Today the engineering principles and economic results of high pressures are so well understood that equal operating safety is generally accepted for all pressures.

If, today, high-pressure steam generators are as safe as low-pressure or medium-pressure installations, and much safer than the boilers up to 225 lb pressure which were being installed well into the years after the War, it is due to fundamental progress in materials, engineering calculations, design and manufacturing methods. However, the design of high-pressure boilers is still in a state of flux.

Proper Design as the Basis of Safety

The investigations and classification of boiler failures by the Association of Owners of Large Boilers have shown that, independent of the materials used, the quality of the feedwater, and operating practice, certain boiler types are susceptible to defects and connection cracks in definite places; for instance, the oval seams in the cross-drum saddles in longitudinal-drum boilers, the seams at the openings of the large connecting pipes of the Garbe boilers, circumferential seams of drums, drumhead flanges with small radii and tube seats subject to high expansion stresses. This is because at these locations high local stresses occur greatly in excess of those caused by the steam pressure alone. The highest stresses are brought about by expansion during operation, by internal heat stresses, bending forces, unroundness, openings, sudden changes in diameter, insufficient ligaments, etc. Such defects have appeared despite rules concerning material and workmanship. Hence it is necessary to so design as to avoid deformations, sudden changes in stress and stress accumulations.

Connections

The logical development of connections has been undertaken only during the last two years, and not all manufacturers have so far been able to solve this problem. It is advisable to substitute tubes of small diameter for all large pipes in order to avoid additional stresses in the drums and headers. The diameter of such tubes is usually made the same as that of all other tubes rolled into the drum. Thus, bolted and welded connections, which are more expensive and might cause undesirable stresses, are avoided. The subdivision of steam outlet and connecting pipes results not only in a more satisfactory distribution of stresses in the drum, but also in better conditions of flow.

Certain difficulties still remain with regard to feedwater connections and desuperheaters, which in most cases have flanged connections. If it is necessary to carry a pipe through the drum shell and the temperature of the latter is different from the temperature of the pipe, a design such as that shown in Fig. 1 may be employed.

In some of the newer German high-pressure boilers superheater tubes have been either welded to the header or have flanged connections (see Fig. 2). Experience has shown, however, that it is possible to avoid this expensive design and to return to simple rolling, if superheater tubes and headers are made of alloy steel, the tensile strength of which is higher than the rolling stress necessary for securing tightness and adhesion.

For this reason it becomes necessary to reduce the diameter of tubes, otherwise the axial pressure of the steam may exceed the adhesion. An increase in the length of the tube seat beyond $1^5/_8$ in. would only cause an increased deformation of the tube wall but not a greater adhesion. A better result is obtained by increasing the thickness of the tube wall, but only up to a certain degree, because thick tubes cannot be sufficiently molded on the outside without, at the same time, damaging the inside surface by the action of the rollers.

In some cases ferrules have proved useful (see Fig. 3). Here the tube is rolled in with adhesive expansion to about 25 per cent decrease in wall thickness, and after that the ferrule is rolled in with equal adhesive expansion. The wall thickness of the ferrule can be equal to, or less than, that of the tube. An especially satisfactory form of the ferrule has proved to be the one where the outside

* Abstracted from *Mitteilungen*, Heft 59, der Vereinigung der Grosskesselbesitzer, (Journal of the Association of Owners of Large Boilers), Berlin, September 15, 1936. Translated by H. R. Taube.

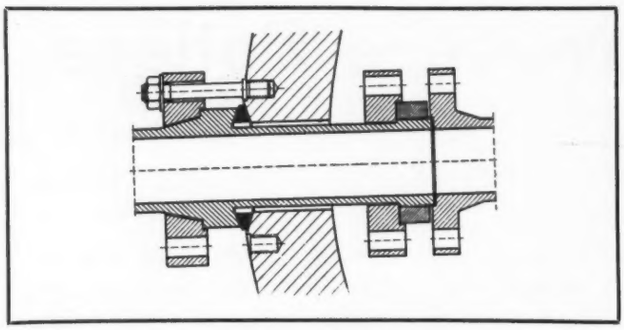


Fig. 1—Penetration of drum wall for feedwater or superheated steam connections

of the tube has an annular excrescence and the ferrule is pressed into the corresponding groove on the inside of the tube. The separate rolling of ferrule and tube makes it possible to shape the tube walls without causing lamination of the inside surface of the tube, as has been observed in tubes with very thick walls. Such ferrules can be used for superheater as well as boiler tubes. The throttling action is insignificant and in most cases desirable. Grooves have proved useful for preventing the tubes from sliding during the rolling process and they also increase the tightness of the tube seat. They should be placed near the flare of the tube.

Because of better resistance against internal pressure, circular headers for superheaters and water walls, and circular sectional headers would seem desirable. However, resistance against rolling pressure is important, and is more advantageous in square headers, which offer a greater supporting surface. Numerous measurements on round headers have shown that tube holes can, during the rolling, become out of round to the extent of $^{3}/_{64}$ in. Screwed connections for superheated steam of over 800 F and for diameters exceeding $1^{1}/_{4}$ to 2 in. are not permissible in Germany, because the threads become loose during the starting-up of the boiler due to temperature differences in the tube.

Steam and Water Flow

The conditions of flow in the water and steam spaces influence the quality of the generated steam. Longitudinal flow in drums and headers is being avoided by subdivision of all connecting pipes into numerous parallel tubes. These tubes are distributed as uniformly as possible over the length of drums and headers. Decreased sections are, if possible, obtained not by reducing the number of tubes, but by reducing the diameter of the individual tubes. Connecting tubes for headers of small cross-section are, if possible, staggered with regard to the tube holes.

In a similar way a separation of steam and water in the upper drum is attained. Especially important is the design of connections for the superheater, because very small differences in pressure in the header effect serious differences in the amount of steam entering the superheater elements. Subdivided connections between drum and superheater are, therefore, advantageous for the flow in both. All later boilers have been designed in accordance with this principle and in many cases the superheater elements have been directly rolled into the drum.

Steam collectors are generally omitted, it being preferable to increase the diameter of the drum. In contrast to American practice, separating devices in the drum are seldom employed in Germany as it is felt that correct and simple direction of flow are more important for obtaining dry steam.

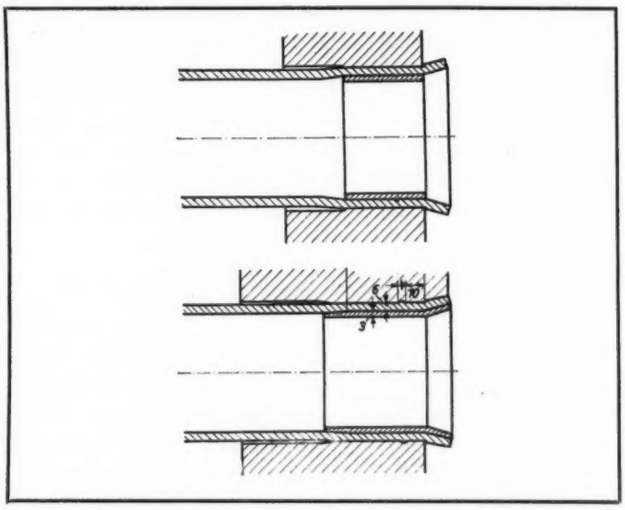


Fig. 3—Ferrules for increasing adhesion of rolled-in tubes

Some publications concerning the calculation of water circulation have made it appear that circulation in highly active riser tubes is imperiled. This does not appear to be the case. To the contrary, the circulated quantity of water is in most boilers much too great, whereby the separation of water and steam is impeded. It is, therefore, frequently advisable to throttle the water circulation. Even today we are still lacking some basic facts for calculating water circulation, particularly as concern the resistance constants of some mixtures, the acceleration by changing ratios of mixture in upward flow and in inclined tubes, the influence of separation of water and steam, etc. It is apparent that we have not yet reached the limit of natural circulation.

The kind of mistake in design that would prevent a riser tube from functioning is shown in Fig. 4. The failure of this tube to function is due chiefly to three causes: (1) the tube receives water immediately from a bundle of downtakes, the temperature of the water being very much below the temperature of saturated steam; (2) the greater part of the tube is only slightly heated and its upper part is intensely heated; (3) the lifting force in the upper third of the tube is not suf-

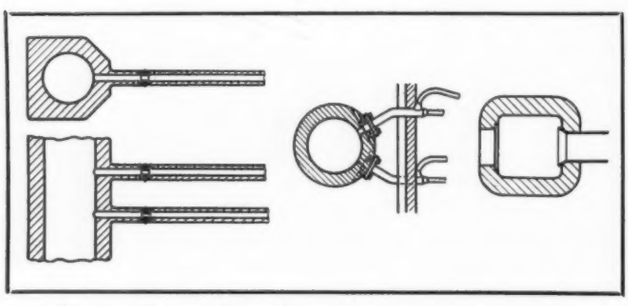


Fig. 2—Connection of superheater tubes to header

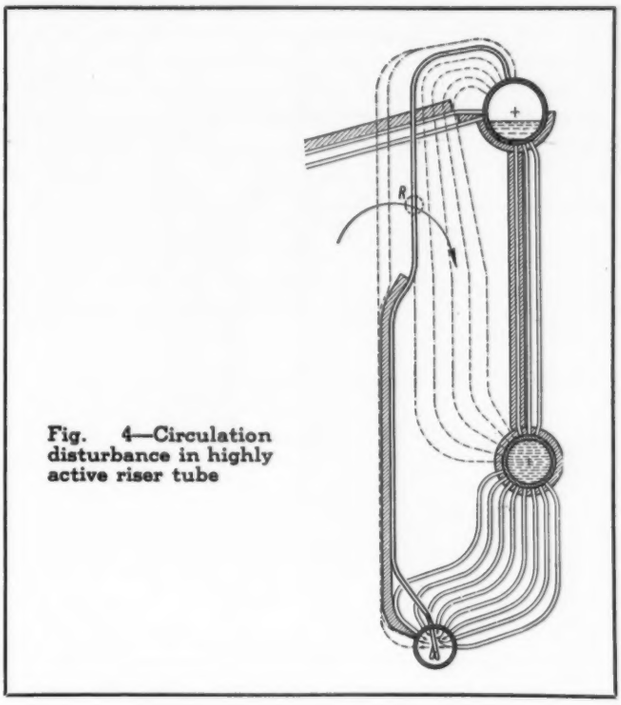


Fig. 4—Circulation disturbance in highly active riser tube

ficient to raise the heavy water column below it, the more so because the offset of the tube is about 7 ft.

As it is possible to avoid the coincidence of such undesirable conditions, it is scarcely necessary to take into consideration defects caused by insufficient water circulation in highly active risers with natural circulation. In particular, it is advisable that in high-pressure boilers feedwater should not have a temperature below that of the saturated steam. The boiler itself is the worst preheater from the point of view of good circulation, and at the same time the most expensive.

In forced-circulation boilers one usually figures with about eight-fold water circulation which, by means of throttling before the water inlet orifice in the tubes, should be distributed uniformly over all the tubes. If care is taken in high-pressure boilers to get rid of all scale and dirt by boiling out before starting, the strainers installed in front of the nozzles will cause no difficulties. Boilers with forced circulation should, under certain conditions, offer some prospects in the transportation field.

Especially important is the circulation during the starting-up of high-pressure boilers. Concern has sometimes been expressed that during this period natural-circulation boilers, particularly those in which tubes enter the drum above the water level, are in danger of being overheated. However, calculations show that the rise in temperature necessary for obtaining the required difference in weight of the water is insignificant and does not present any danger for the tube walls. This has been confirmed by the fact that overheating has not been observed.

Superheaters present a different problem. They require special protection, because in high-pressure boilers, in order to obtain a flat temperature characteristic of the superheat, there are provided only a few rows of boiler tubes between the furnace and the superheater. For this reason high-pressure boilers in Germany have been equipped with circulating pumps which, during the starting-up period, pump water from the lower drum into the upper drums. About 40 to 60 per cent of the highest continuous capacity of the boiler is circulated during the starting-up period. The velocity of the water varies from 0.6 to 1.3 ft per sec.

In two recent superposed high-pressure installations the superheater is kept filled with water up to 225 to 300 lb pressure, then emptied and connected through the pressure regulating valve with the low-pressure pipe line. Steam flowing through the superheater at this pressure is sufficient to keep it cool.

Gas and Air Flow

The design of the boiler should be such that not only the convection heating surface is well exposed to the flue gases, but also that the superheater is uniformly heated at all loads. This is necessary for obtaining a flat superheat temperature characteristic. These principles have not been sufficiently followed in some recent installations.

A flat temperature characteristic is also favored by suitable arrangement of the tube rows of the superheater. Wide passages must be avoided, because the elements adjacent to them acquire a higher temperature on account of the greater quantity of gas flowing over them and, therefore, they have a tendency to become overheated. Staggering of tubes results in flatter temperature characteristics than where tubes are arranged in parallel, if the latter be unfavorably spaced. In tube banks with parallel tubes, a flat temperature characteristic can also be attained by making the distance between tubes greater in the direction of flow than in the direction normal to it. If, on the contrary, the spacing in the direction of flow is comparatively small, the part of the tube circumference coming in contact with the gases will be smaller, especially at low loads. With rising load the gases will envelop the tubes more completely and this has the same effect as if the

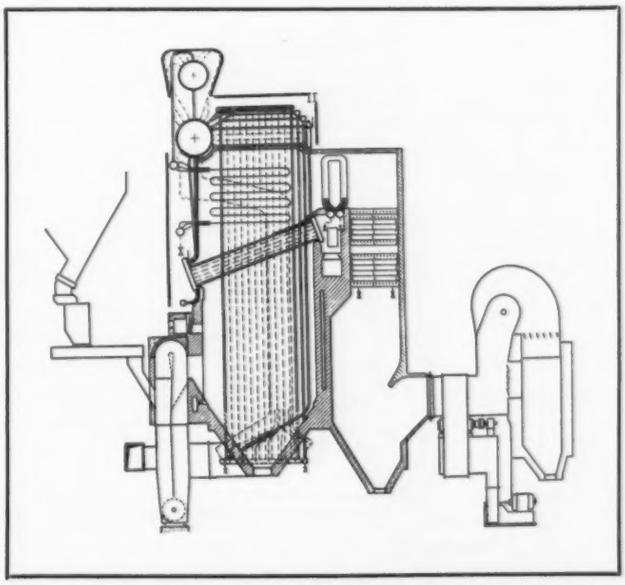


Fig. 5—Steinmuller sectional-header boiler with mill firing; maximum continuous capacity 88,000-lb per hr, 1870-lb working pressure, 900 F steam temperature

superheating surface had been increased. In consequence, the temperature will rise in greater measure with rising load.

A favorable gas flow over the heating surfaces can in many cases be attained by employing guiding vanes. This arrangement also has the advantage that draft loss is reduced. The draft loss with vanes is only a fraction of that in bends with free cross-section. Moreover, the flow is distributed uniformly over the cross-section, so that even in case several sets of vanes are installed one after another, no turbulence or stratification occurs. For changes in direction down to 30 degrees it is advisable to use vanes if avoidance of draft losses is desirable, and for even smaller angles if importance is attached to uniform distribution of velocities behind the bend.

Separation of Water and Steam

Figs. 5, 6 and 7 refer to three different types of high-pressure boilers for three different installations in Germany and built by three different boiler companies. Nevertheless, it is remarkable to what an extent the three boilers resemble each other in their general characteristics and how similar are the measures provided for separation of water and steam. These boilers have the following features in common: All three are pulverized-coal fired, one by means of a Kraemer mill, while the other two have corner burners. Two burn bituminous coal, and the third is designed for burning brown coal. The heating surfaces of each are to the fullest extent arranged around the combustion chamber, and the greatest part of the steam is produced by the water walls. The convection heating surface, situated between the furnace and the superheater, is reduced to an almost insignificant amount. This heating surface which was once the boiler, properly speaking, now serves principally to protect the superheater. In consequence, its connection with the drum is important only from the point of view of practical utilization of space.

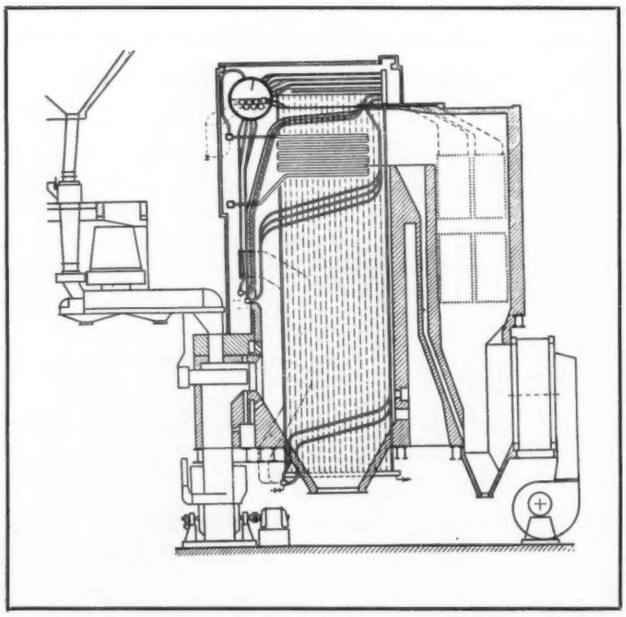


Fig. 6—B & W steep-tube radiation boiler with mill firing; maximum continuous capacity 172,000-lb per hr, 2200-lb working pressure, 890 F steam temperature

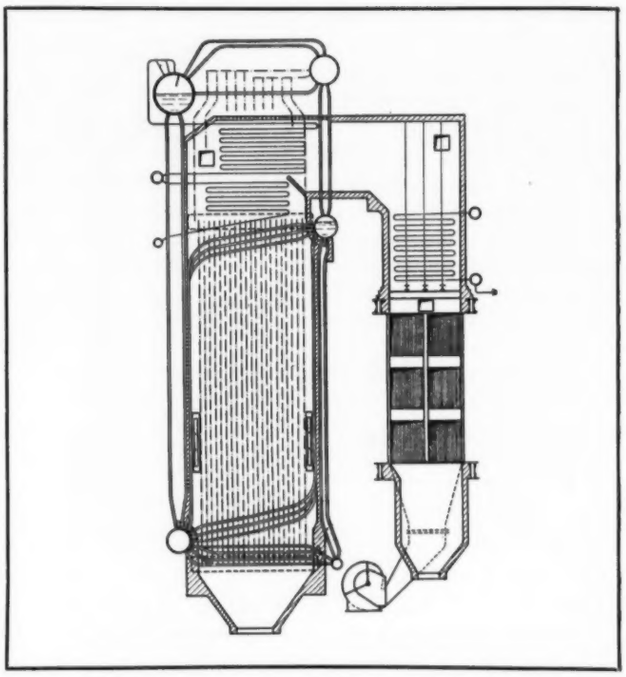


Fig. 7—KSG high capacity radiation boiler with corner firing, built for 264,000-lb per hr, 2000-lb working pressure and 920 F steam temperature

One of the three boilers, to use a once customary name, could be called a steep-tube boiler, one a sectional-header boiler and the third a combination of the two types. Despite these apparent differences, the arrangement of the heating surfaces is basically the same. The superheaters are placed horizontally and can, therefore, easily be filled, ventilated and emptied. After the superheater follow only the riser tubes of the water walls representing some additional boiler heating surface, and then the preheaters. The riser tubes are not directly connected with the upper drum, but instead with sectional headers, horizontal headers or an intermediate dry drum. From these intermediate parts horizontal tubes lead into the upper drum.

In all three types surface desuperheaters, between the primary and secondary superheaters, are provided in the upper drum. The superheaters are connected with the upper drum by means of numerous tubes. In one case the superheater tubes have been rolled directly into the drum. In all three boilers the sidewall furnace tubes are perfectly straight. These walls are not directly connected with the upper drum, but the connection is made through a header which makes it possible to distribute the water-steam mixture uniformly over the whole length of the upper drum.

In the KSG boiler (Fig. 7), only about 10 per cent of the water-steam mixture flows into the upper drum. Because of the pressure drop in the vertical risers, the water in the intermediate drum is lowered and a water level is formed. The greater part of the circulating water flows from this drum back into the lower drums. The mixture rising upward consists of two-thirds, by weight, of steam and one-third water. The water level established in the intermediate drum has been found to be real, which is demonstrated by the composition

of the water-steam mixture, and also by the fact that this level changes with changing loads.

In all these high-pressure boilers the feedwater is preheated as nearly as possible to the temperature of saturated steam. The economizers are small because it is usually necessary to raise the water temperature only about 180 deg F. Preheating with bled or exhaust steam brings the temperature of the feedwater entering the economizer up to about 400 F.

The foregoing observations apply also to forced-circulation and forced-flow boiler types, because their designs are much more influenced by furnace and gas flow than by water circulation. The only exception is the Velox boiler in which the design on the gas side is very different.

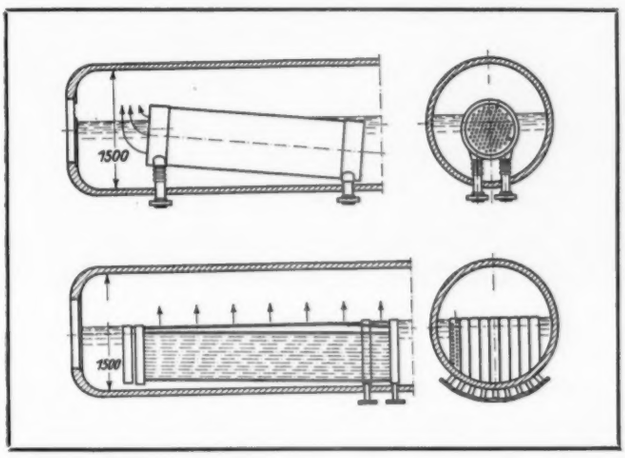


Fig. 8—Heat transfer coils in upper drum of indirectly heated boiler; sectional heating elements in lower view

Only one of the three boilers illustrated has a steam collector in the top drum. In the so-called indirect boilers the heat transfer in the drum is significant for the generation of dry steam. As an example, the transfer devices of a Schmidt boiler are shown in Fig. 8. It had been proposed at first to condense the primary steam in tube bundles, which were to be placed below the water level of the upper drum. Such an arrangement would probably have shown defects from the point of view of safety and correct flow. Because of the small incline of the tube bundles the steam-water mixture forming in them would not flow out quietly and steadily but, to judge by observations, with interruptions and jerks. The water level in the upper drum would, in consequence, be irregularly affected in a limited area and carryover of water would be increased. Due to the great difference in the wall thickness of the drum and of the tubes of the inserted tube bundles (the first being about ten times that of the latter), the tubes would, during the starting-up period, be heated more quickly and would follow changes in pressure much more readily. A loosening or even tearing out of the tube seats would likely result. Taking into consideration the great difference in pressure between heating steam and operating steam, this would lead to a quick evaporation of all water covering the heating surface exposed to flame, or at least to a wiping out of the advantage of the separation of heating medium flow and operating steam.

In a recent installation of this boiler sectional heating elements were used with primary steam flowing through the tubes. The boiler water of the upper drum flows over the outside of the tube bundles. Such a heating element can freely expand and the steam bubbles can rise evenly over the whole water surface in the upper drum. Results of tests show that, even for high salt content and a high soda figure for the boiler water, the salt content of the steam is very low. Sectional heating elements offer, however, much greater difficulties in removing the scale than the tube bundles, which can be cleaned by turbining.

Standardization

Too long the belief has prevailed that the performance of power plant equipment, in particular of boilers and turbines, should correspond to the requirements existing at the time the design is prepared. This view has resulted in a great diversity of types and sizes and at the same time in extended delivery and higher prices. If a considerably smaller number of types could be continuously built, it would be possible to reduce greatly the time of delivery and also to some extent, prices. At the same time such a policy would result in improved quality, greater efficiency and safety, because then it would be possible to give more attention to calculations, design and manufacture. Everything could be thought out more carefully and produced without haste, and many parts could be furnished from stock quicker and cheaper.

For this reason some degree of standardization has already been invoked in Germany. Recently, as the first requirement, certain pressures and temperatures have been prescribed and standardization of capacity is to follow. The latter will be based on the heat generated in the combustion chamber and for this a series can be developed. It will be possible to design the furnace water walls in accordance with the fuel used and its physical and chemical properties, and to design the superheater and the heating surface following it in accordance with the required pressure and temperature. This series, based on the heat generated in the combustion chamber, can be designated for sales purposes as capacity series in pounds per hour.

This capacity standardization is again only an intermediate step in the direction of standardization of the single parts and in the design of the boiler. A number of parts, such as handhole plates, are already ripe for standardization.

Careful analysis usually reveals that there is little worthwhile in small deviations from known forms and they should be disregarded in favor of the broad lines of development. In this way a smaller number, but more mature types will be obtained, types which are simple, economical and safe in operation, even if they deliberately forego some apparently special advantages.

Attention has been called to a misprint in the caption of Figure 1 accompanying the paper on "High Spots of German Power Plant Practice," by Professor Schöne, in the October issue. The steam conditions as printed were 1260 lb and 840 F. These should have been 2100 lb and 932 F.

1

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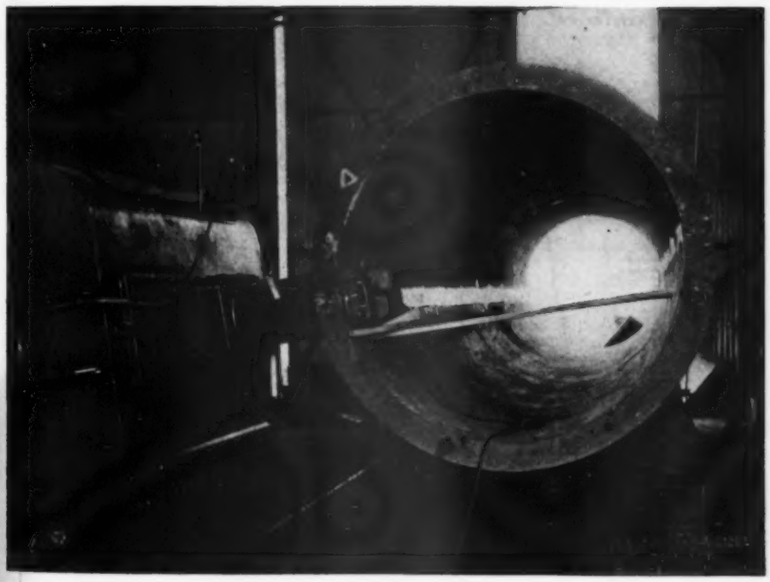
FABRICATION OF HIGH-PRESSURE DRUMS FOR WATERSIDE BOILERS

These drums are 60 in. diameter, 5 in. thick and are designed for 1400 lb steam pressure. They are fusion welded.

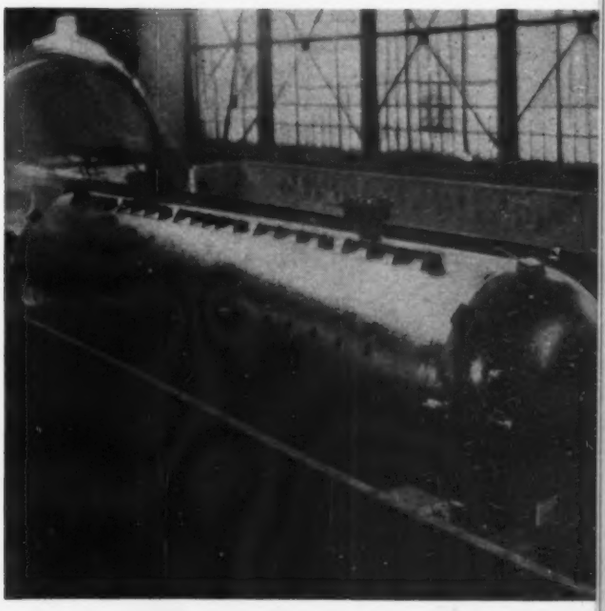
5



6

7

1 Pressing 5 in. plate to 60 in. diameter circle
2 Plate after first stage operation
3 Machining longitudinal weld grooves
4 Shell end boring machins, facing circumferential weld seam
5 View of annealing furnace
6 Photographic examination of longitudinal weld seam
7 Drilling tube holes in finished drum with drill jig in place
8 Drum loaded on car for shipment



8

ALABAMA COALS—
Their Classification and Analyses

By P. B. PLACE
Combustion Engineering Company, Inc.

Previous articles of this series have dealt with Ohio, Kentucky, Virginia, Illinois, Indiana, Pennsylvania, Tennessee and Maryland bituminous coals. In each case, as in the present article, the individual seams are traced through various counties, the coals are identified by county and trade names, and their characteristics and analyses are given. Knowing the source of an Alabama coal, its moisture and ash content, a complete analysis may be set up from the values given in the tables which will be sufficiently accurate for most power plant purposes.

GEORGIA has several thousand square miles of coal-bearing area in the northern half of the State. This area constitutes the southern tip of the Appalachian region and is a continuation of the Tennessee belt, extending from the northeast corner of the State southwest through the Birmingham section. The accompanying map shows the general area that is underlain with coal and the location of the four more or less separated fields in the State.

Although the coal areas in Alabama cover twenty or more counties, the bulk of the present production comes from only four or five counties and, as is shown in Table I, Jefferson and Walker counties contribute over three-quarters of the output. The total production for the State constitutes only two or three per cent of the bituminous production of the United States and most of this coal is consumed within the State. There are at present undeveloped coal areas which are likely to become important with increased industrialization of the South.

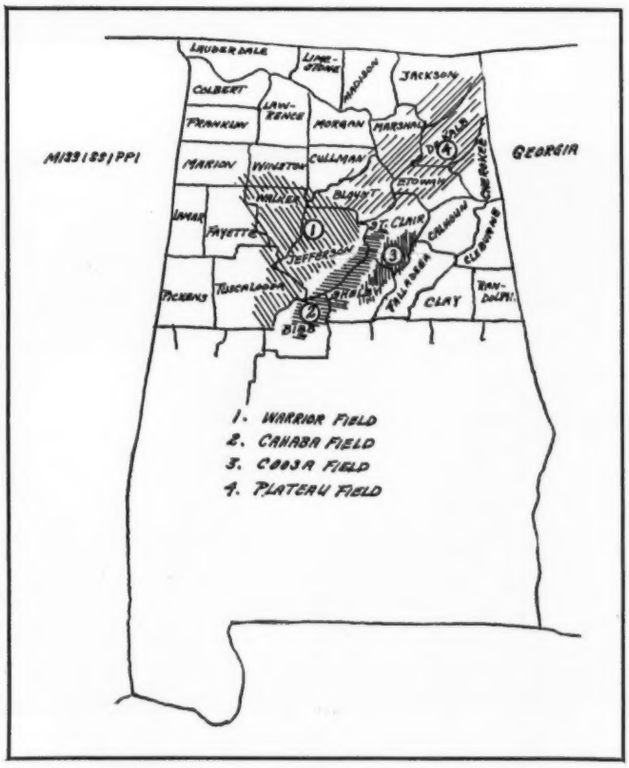
TABLE I—RELATIVE PRODUCTION IN PRINCIPAL PRODUCING COUNTIES

	1929	1930	1931	1932
Jefferson county	49.6	50.3	49.9	44.4
Walker county	28.3	28.8	28.8	32.3
St. Clair county	4.4	4.9	6.3	7.0
Bibb county	5.8	5.3	4.3	5.2
	88.1	89.3	89.3	88.9

TABLE II—COAL FIELDS IN ALABAMA AND COUNTIES INVOLVED

1. Warrior Field
   Jefferson, Walker, Tuscaloosa, Fayette and Marion counties
2. Cahaba Field
   Jefferson, St. Clair, Bibb and Shelby counties
3. Coosa Field
   St. Clair and Shelby counties
4. Plateau Field
   Blount, DeKalb, Marshall and Jackson counties

Table II gives the four principal coal areas in the State and the principal counties involved in these areas. It is evident from this table that there is no sharp distinction between field and county boundaries, both the Warrior and Cahaba fields crossing Jefferson county and Cahaba and Coosa fields crossing both St. Clair and Shelby counties. A number of other counties are involved in the Warrior and Plateau fields which are not of much importance.



Coal fields and their locations in several Alabama counties

Some thirty to forty different coal seams have been identified and named throughout the state but data correlating seams in different fields and identifying them with seams in adjacent states are meager. To clarify the confusion resulting from a multiplicity of local seam names, Alabama coals have been grouped into the following classification as given in the *Keystone Coal Buyers Manual.*

1. Big Seam
   American, Mary Lee, Blue Creek—Jefferson, Walker Counties
   Henry Ellen—St. Clair County

TABLE III

TYPICAL INDIVIDUAL ANALYSES
OF
ALABAMA COALS

As Received				Moisture and Ash Free					
Moisture	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu / lb
1. Jefferson County									
Mary Lee Bed									
2.9	12.1	31.8	68.2	1.5	5.3	86.8	1.9	4.5	15360
3.1	11.1	33.4	66.6	0.9	5.4	86.3	1.8	5.6	15380
2.3	10.0	33.9	66.1	0.9	5.6	87.4	1.8	4.3	15380
2.1	11.8	31.0	69.0	1.2	5.3	86.9	1.9	4.7	15330
1.8	9.4	33.5	66.5	0.9	5.5	86.5	1.8	5.3	15510
Pratt Bed									
1.7	4.6	32.5	67.5	1.5	5.3	87.0	1.7	4.5	15580
2.3	4.9	32.5	67.5	1.4	5.2	87.6	1.7	4.1	15530
3.0	6.5	31.1	68.9	1.9	5.5	87.4	1.5	3.7	15550
2.2	6.1	31.4	68.6	1.8	5.3	87.1	1.7	4.1	15520
2.5	6.9	31.0	69.0	1.5	5.2	87.3	1.8	4.2	15530
2. Walker County									
Black Creek Bed									
2.8	1.9	37.4	62.6	0.7	5.6	85.9	1.9	5.9	15290
2.6	1.9	39.1	60.9	0.8	5.6	85.3	1.9	6.4	15210
3.2	2.8	39.3	60.7	1.1	5.6	84.7	1.9	6.7	15160
3.6	2.6	38.3	61.7	1.0	5.5	85.1	1.9	6.5	15210
Jagger Bed									
4.4	10.7	39.1	60.9	0.8	5.5	81.9	1.9	9.9	14700
2.7	23.9	40.5	59.5	0.7	5.6	82.7	1.5	9.5	14560
4.3	10.7	39.8	60.2	0.9	5.5	81.9	1.9	9.8	14700
3. St. Clair County									
Harkness Bed									
2.5	7.9	37.7	62.3	2.6	5.4	83.9	1.9	6.2	15100
2.5	11.4	38.5	61.5	1.0	5.5	84.6	1.9	7.0	15190
2.0	12.4	37.3	62.7	2.2	5.4	84.4	2.0	6.0	15060
4. Shelby County									
Gholson Bed									
3.1	4.2	37.4	62.6	0.7	5.5	85.4	1.6	6.8	15230
3.0	4.4	35.2	64.8	0.7	5.5	87.0	1.5	5.3	15370
6.0	2.3	36.9	63.1	0.6	5.6	85.5	1.6	6.7	15250
5. Bibb County									
Thompson Bed									
3.5	9.9	36.6	63.4	0.8	5.3	83.9	1.3	8.7	15050
2.5	11.3	39.6	60.4	0.6	5.5	84.7	1.2	8.0	14980
3.1	6.1	38.5	61.5	0.5	5.5	84.0	1.4	8.6	14930

2. Black Creek
   Black Creek—Jefferson, Walker, Blount, Marion Counties
   Jefferson—Jefferson County
3. Cahaba
   Clark, Gholson—Bibb, Shelby Counties
   Harkness, Helena, Thompson—Jefferson, St. Clair, Shelby, Bibb Counties
4. Carbon Hill
   Jagger—Walker, Fayette Counties
5. Corona
   Corona—Walker County
6. Montevallo
   Montevallo—Shelby County

Another classification of Alabama coals is by groups of adjacent beds. The principal groups and member seams are as follows, the Mary Lee and the Pratt groups being the largest producers:

1. Mary Lee Group
   Blue Creek, Jagger, Mary Lee—Jefferson, Walker, Tuscaloosa Counties
2. Pratt Group
   Pratt, Corona, Nickel Plate, American—Jefferson, Walker Counties

TABLE IV

AVERAGE ANALYSES OF ALABAMA COALS FROM PRINCIPAL COUNTIES

As Received		Moisture and Ash Free							
Moisture	Ash	Volatile Matter	Fixed Carbon	Sulphur	Hydrogen	Carbon	Nitrogen	Oxygen	Btu / lb
1. Jefferson County									
Blue Creek Bed 3-4	8-10	26.9	73.1	0.9	5.3	88.2	1.7	3.9	15560
Pratt Bed 2-4	4-10	31.5	68.5	1.6	5.3	87.2	1.7	4.2	15540
Mary Lee Bed 2-3	7-14	32.6	67.4	1.2	5.4	86.5	1.9	5.0	15370
Black Creek Bed 2-4	2-5	33.6	66.4	0.8	5.3	86.8	1.9	5.2	15460
American Bed 3-4	3-5	33.8	66.2	1.3	5.4	86.8	1.9	4.6	15390
Jefferson Bed 2-3	3-9	34.6	65.4	2.9	5.3	85.0	1.8	5.0	15340
Nunnally Bed 2-3	6-12	36.7	63.2	1.2	5.5	85.6	1.8	5.9	15220
2. Walker County									
Mary Lee Bed 2-4	11-15	36.7	63.3	0.8	5.5	83.5	1.9	8.3	14790
Black Creek Bed 2-4	2-4	38.3	61.7	0.9	5.5	85.2	1.9	6.5	15190
Pratt Bed 1-4	6-8	38.4	61.6	1.9	5.6	84.2	1.9	6.4	15160
American Bed 2-3	7-9	38.9	61.1	1.8	5.6	83.9	1.9	6.8	14970
Jagger Bed 2-5	10-16	39.7	60.3	1.0	5.6	81.9	1.8	9.7	14620
3. St. Clair County									
Broken Arrow Bed 3-4	8-10	32.4	67.6	1.7	5.4	87.3	1.5	4.1	15560
Coal City Bed 2-3	3-5	35.7	64.3	1.2	5.4	87.7	1.6	4.1	15700
Helena Bed 3-5	4-6	37.0	63.0	1.0	5.6	84.6	1.8	7.0	15070
Harkness Bed 2-4	8-12	37.3	62.7	2.2	5.5	84.2	1.9	6.2	15140
4. Bibb County									
Youngblood Bed 3-5	5-12	36.5	63.5	1.2	5.5	86.1	1.5	5.7	15410
Woodstock Bed 2-4	3-10	37.8	62.2	1.2	5.4	85.5	1.5	6.4	15175
Thompson Bed 3-5	3-13	38.0	62.0	0.8	5.4	84.4	1.3	8.1	14990
Gholson Bed 3-7	9-18	38.3	61.7	1.3	5.5	84.3	1.5	7.4	15190
Clark Bed 2-5	6-8	38.7	61.3	0.9	5.4	84.9	1.4	7.4	15230
5. Shelby County									
Thompson Bed 2-4	5-10	35.6	64.4	1.2	5.4	84.3	1.4	7.7	15080
Gholson Bed 3-6	2-5	36.4	63.6	0.7	5.5	85.8	1.5	6.5	15300
Helena Bed 2-5	5-11	38.3	61.7	0.6	5.6	84.8	1.6	7.4	15095
Clark Bed 2-3	6-11	39.3	60.7	0.7	5.5	85.0	1.5	7.3	15200
Montevallo Bed 2-4	5-10	39.5	60.5	0.9	5.5	84.4	1.3	7.9	15105
6. Tuscaloosa County									
Blue Creek Bed 4-5	8-10	27.7	72.3	0.7	5.3	87.3	1.7	5.0	15550
Jagger Bed 2-3	8-10	28.3	71.7	0.7	5.1	88.3	1.8	4.1	15585
Milldale Bed 2-5	3-8	33.0	67.0	1.1	5.5	86.3	1.6	5.5	15400
Brookwood Bed 2-5	8-10	33.2	66.8	1.2	5.4	86.2	1.7	5.5	15330

TABLE V

AVERAGE ANALYSES FOR ALABAMA COALS

Counties	Beds		As Received	Moisture Free or Dry	Moisture and Ash Free
Jefferson	Mary Lee	Moist.	3.0	-	-
	Jefferson	Ash	7.0	7.22	-
	Black Creek	V. M.	29.88	30.80	33.2
	Gould	F. C.	60.12	61.98	66.8
	American		100.00	100.00	100.0
	Pratt	S	1.26	1.30	1.4
	Nickel Plate	H	4.77	4.92	5.3
Tuscaloosa	Milldale	C	77.49	79.88	86.1
	Brookwood	N	1.62	1.67	1.8
		O	4.86	5.01	5.4
			90.0	92.78	100.0
		Btu/lb	13840	14270	15380
Walker	Mary Lee	Moist.	3.5		-
	American	Ash	8.0	8.29	-
	Jagger	V. M.	33.54	34.76	37.9
	Black Creek	F. C.	54.96	56.95	62.1
	Pratt		100.00	100.00	100.0
Shelby	Montvallo	S	1.06	1.10	1.2
	Clark	H	4.87	5.04	5.5
	Helena	C	74479	77.50	84.5
	Maylene	N	1.50	1.56	1.7
St. Clair	Helena	O	6.28	6.51	7.1
	Harkness		88.50	91.71	100.0
Bibb	Thompson	Btu/lb	13340	13825	15075
	Gholson				
	Clark				
Jefferson	Harkness				
	Nunnally				
Jefferson	Blue Creek	Moist.	3.0	-	-
	Nickel Plate	Ash	8.0	8.25	-
Tuscaloosa	Blue Creek	V. M.	24.03	24.77	27.0
	Jagger	F. C.	64.97	66.98	73.0
			100.00	100.00	100.0
		S	0.62	0.64	0.7
		H	4.63	4.77	5.2
		C	78.50	80.93	88.2
		N	1.51	1.56	1.7
		O	3.74	3.85	4.2
			89.0	91.75	100.0
		Btu/lb	13855	14285	15570

3. Black Creek Group
   Black Creek, Jefferson—Jefferson, Walker Counties
4. Brookwood Group
   Brookwood, Milldale—Tuscaloosa County

Typical individual analyses on a moisture- and ash-free basis, of Alabama coals are given in Table III. These analyses show the similarity expected for coals mined in the same area; and from the same seam and from similar tables, the average analyses given in Table IV have been determined. These averages may be used in the absence of more reliable data, to set up a complete analysis for an Alabama coal for a given moisture and ash content. The range of moisture and ash values are given in the table.

Although it is impossible to give a single analysis for an Alabama coal, seams of similar analysis have been grouped in Table V and complete analyses, as received, dry, and moisture- and ash-free, have been set up for assumed moisture and ash contents. These analyses may be used for general purposes without incurring serious error.

As stated above, most of the State's production is used within the State for steam, domestic and coking purposes. In general, the coking coals come from the Warrior field and the steam coals from the Cahaba field. The latter are fairly hard, come in prepared sizes, are cleaned and stand shipment well. They are best burned on stokers of the underfeed type or in pulverized form.

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SMALL SIZE FORGED STEEL STEAM TRAP

HERE is good news for power engineers—a forged steel trap by Armstrong priced only a little above ordinary cast steel! Designated as No. 312 (½" or ¾"), this new trap is fully equal in quality to other Armstrong forged steel traps but is priced lower because of smaller size. Especially designed for handling small drip jobs at pressures from 250 to 450 lbs., No. 312 can also be used to an advantage on jobs ranging from 150 to 250 lbs. *with superheat.* Because of low price, it is economical to install one of these traps ahead of every high pressure valve where condensate might accumulate and cause trouble due to cooling of disc. *Write for complete information.*

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Surcharges on Coal Freight Rates Discontinued

The Interstate Commerce Commission, by its decision of December 18, 1936, denied the petition of Class I railroads for further extension of existing emergency freight rate surcharges on bituminous coal. These surcharges were originally authorized by the Interstate Commerce Commission as a means of affording emergency relief to the railroads. Any extensions beyond their original expiration date have been opposed by the Consumers' Counsel and by the National Bituminous Coal Commission, on the grounds that the emergency had passed, and that the surchages, in so far as they apply to bituminous coal, constitute an excessive and unreasonable burden upon consumers and upon an already depressed industry.

Under this decision of the Interstate Commerce Commission, resulting savings in carload transportation charges on bituminous coal will amount to about $2,500,000 monthly.

The Elgin Softener Corporation, Elgin, Illinois, announces the appointment of **C. T. Parker,** who will represent the company in New York State. His office will be located at 184 Broadway, Rochester, N. Y.

R. B. Howland has recently been made a vice-president and director of United Engineers & Constructors, Inc., Philadelphia. Since 1929 assistant to the president of the company, Mr. Howland was previously associated with Stone & Webster and later with Dwight P. Robinson & Company.

Theodore Maynz, for a number of years consulting engineer in Cleveland, has lately joined the engineering staff of Gibbs & Hill, New York.

P. T. Wetter, for the past ten years on the staff of the American Society of Mechanical Engineers, in charge of Professional Division activities, has resigned to become executive vice-president of the American Cutting Alloys, Inc., 500 Fifth Avenue, New York.

J. E. Tobey, manager of the fuel engineering division of Appalachian Coals, Inc., has been chosen chairman of the Ohio Valley Section of the American Institute of Mining and Metallurgical Engineers.

J. I. Robinson, since 1919 associated with the Canadian branch of Crane Co., became, on January 1, vice-president of Crane Co. Ltd., Montreal, succeeding J. A. Murphy who retired from active service after fifty-one years with the company.

G. R. Brophy has joined the development and research staff of the International Nickel Company at its research laboratory in Bayonne and will be engaged in research problems relating to nickel alloy steels.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Fumes from Battersea Station

The annual report of the Chief Inspector for the Minister of Health (England), which is abstracted in the November issue of *The Fuel Economist*, deals with atmospheric pollution by various classes of industries and contains the following statement with reference to Battersea Station:

"Estimations of the acidity contained in the waste gases emitted from the chimneys of the Battersea Power Station have been continued. The washing plant has operated in an entirely satisfactory manner and both chimneys are now fitted with automatic sulphur oxide recorders. The average of the official tests made was 0.012 grain (expressed as sulphur) per cubic foot of dry gas and the average of some hundreds of work's tests was 0.019 grain."

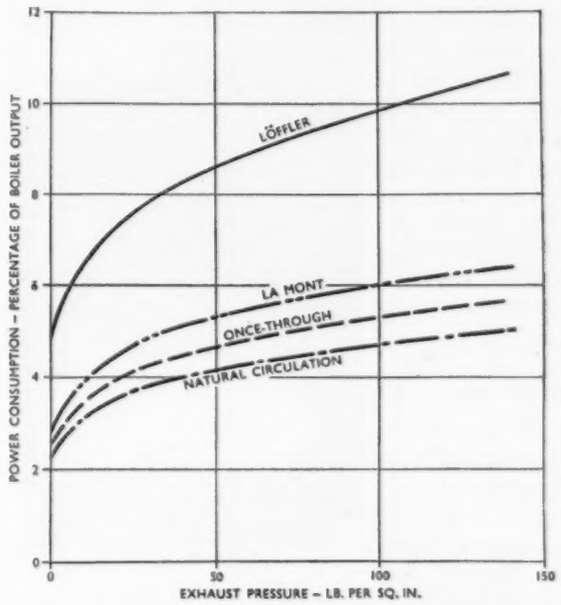
Forced-Circulation, Once-Through and Natural Circulation Boilers Compared

In a paper entitled "Modern Forms of Water-Tube Boilers for Land and Marine Use," read before the Institution of Mechanical Engineers (Great Britain), Dr. Friedrich Münzinger, well-known German engineer, differentiated between forced-circulation and once-through boilers, compared the power required by the feed and circulating pumps for several types and commented on various factors involved.

Forced-circulation boilers, in which steam or water continuously pass through the heating surface (as in the Loeffler, La Mont and Velox types), must be differentiated from once-through boilers (as the Benson and Sulzer types) in which exactly as much water is forced through the heating elements as is converted into steam. While forced-circulation boilers can be blown down like ordinary boilers, in the once-through type, either water must be tapped continuously or a part of the heating surface must be scavenged from time to time. Moreover, in forced-circulation boilers impurities in the feedwater can separate out in the drum, but in once-through boilers any impurities not deposited on the heating surfaces pass on to the turbine. Once-through boilers, therefore, require very pure feedwater.

The relative power required by the feed or circulating pump is greatest in the case of the forced-circulation boiler and least with natural circulation as is shown in the accompanying curves.

Liability to disturbance under sudden removal of load depends on the amount of steam in the boiler and superheater and on the water equivalent of the boiler. Hence, the most sensitive type is the once-through, the forced-circulation is next and the natural-circulation type is least affected. For example, with an evaporation of 18.5 lb per sq ft per hr immediately preceding the change in load, the process of regulation must be completed within $3^1/_2$ sec for once-through boilers, $7^1/_2$ sec for forced-circulation boilers, $10^1/_2$ sec for small-tube natural-circulation boilers (as in some marine types)



Power required by feed and circulating pumps

and 22 sec for stationary boilers employing tubes of the usual diameter and drum capacities.

Furthermore, with once-through boilers, artificial flow must be provided during the commencement of firing and a certain minimum quantity of steam must be produced at all times, whereas the forced-circulation type can be heated and operated like an ordinary boiler.

Kearsley Station

Typical of British practice in the extension and modernization of existing steam stations is that of the Kearsley Generating Station of the Lancashire Electric Power Company, described in *Engineering* of December 25.

This station, as built in 1927, contained eight 75,000-lb per hr boilers supplying steam at 315 lb, 710 F, to two 32,000-kw turbine-generators. For a time it was the most efficient station in England, operating on 1.17 lb of coal per kwhr at a thermal efficiency of 23.84 per cent and 42.3 per cent load factor. In 1934 the output of the boilers was increased to 95,000 lb per hr each by installing water-cooled furnaces.

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DIAL TYPE

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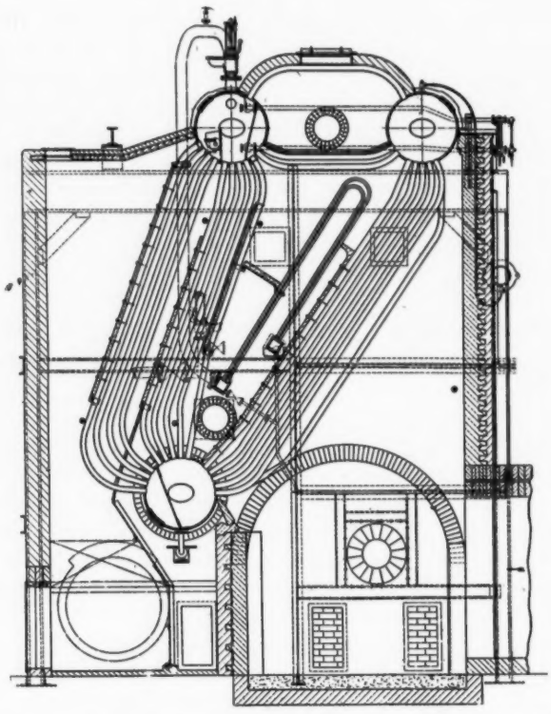
To meet increasing load demands four new boilers and a 51,600-kw, 1500-rpm turbine-generator were installed last year. These boilers each have a maximum rating of 173,000 lb per hr and the steam conditions have been raised to 620 lb and 850 F. It is anticipated that the plant efficiency will be increased thereby about 16 per cent. These boilers are equipped with economizers and are fired by traveling grate stokers 25 ft wide and 20 ft long. Condensing water for the turbine is cooled by a concrete cooling tower.

Waste Heat Installation

An interesting installation of power generation from waste heat at the Derby Foundry of Ley's Malleable Casting Company, Ltd., is described in the December issue of *Engineering and Boiler House Review.* Here



Section through boiler showing waste gas duct and pulverized coal burner

the metallurgical plant consists of six melting furnaces, twenty-six annealing ovens and four reheating furnaces, all fired by pulverized coal. The power plant consists of three Stirling type boilers designed for 200 lb pressure and 600 F steam temperature supplying two 1350-kw and one 300-kw condensing turbine-generators. The boilers operate on waste gases from the metallurgical plant and when this is insufficient to meet the power demands, it is supplemented by pulverized coal from the storage system.

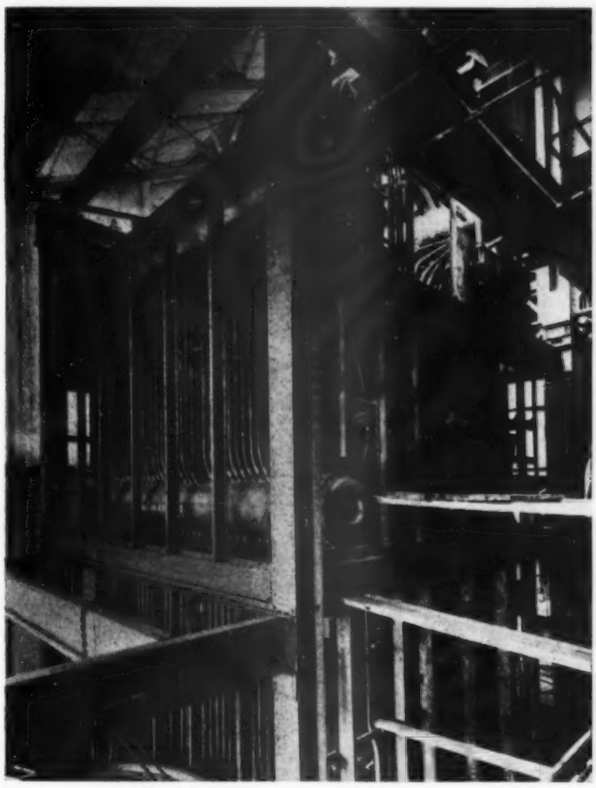
Each boiler is arranged to operate in conjunction with two melting furnaces, a single chimney being situated between them. At the top of this chimney is a damper by means of which the waste gases can be released if the boiler is not required or is out of service. In addition, the boiler has its own stack.

A section of one of the boilers is shown in the accompanying sketch which illustrates the duct whereby the

waste gas is admitted, and also the position of the auxiliary pulverized coal burner located in the side wall where the waste gases enter. In the other two boilers, the preheated air is supplied to the melting furnaces and not directly to the boilers. Any air not so utilized is supplied for heating the foundry.

Boiler Plant Extension at Leicester

The new steam generating unit being installed at the Freeman's Meadow Station, Leicester, England, completes the equipment to be installed in the boiler house already containing three pulverized-coal-fired boilers put in about five years ago.



Boiler before installing the casing

The new boiler is of the International Combustion, Ltd., single-pass type, capable of a maximum continuous output of 180,000 lb per hr and a two-hour peak of 200,000 lb. The steam conditions are 360 lb and 800 F. Solid forged drums with riveted ends are employed and the combustion chamber is enclosed by bare tubes closely pitched with a slag screen also of plain tubes.

Corner firing is employed, there being two burners per corner supplied with pulverized coal carried by primary air from feeders situated under a storage bunker. A 15-ton Raymond mill has been added to augment the mills already supplying the Lopulco system. The coal is dried in the mill by hot flue gases, the vents leading to the combustion chamber.

Feedwater is supplied at 300 F through a gilled-tube economizer of the steaming type and two Howden-Ljungstrom air heaters deliver air to the burners at 412 F. The induced-draft fan of the double-inlet type, one inlet for each air heater section, has a cast-iron casing.

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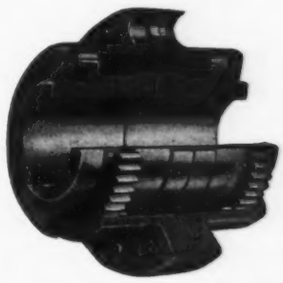

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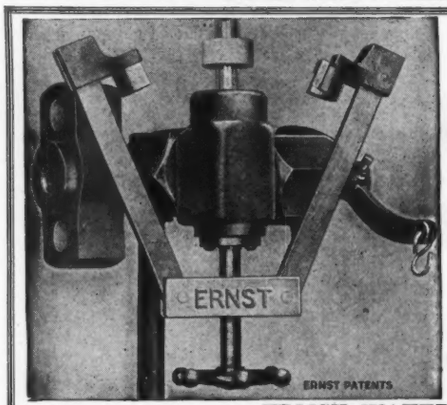

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